

# **Mercury Cycling in Aquatic Ecosystems: Things that Matter other than Loading**

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**Presentation to the Utah Statewide Mercury  
Workgroup  
November 18, 2008**



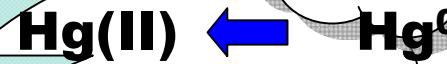
## Presentation Outline:

- How important are variations in Hg loading (time and space)?
  - METAALICUS project
  - ACME (Everglades) project
  - Midwest Lakes survey
- Reservoirs – what can be done?
- Discussion

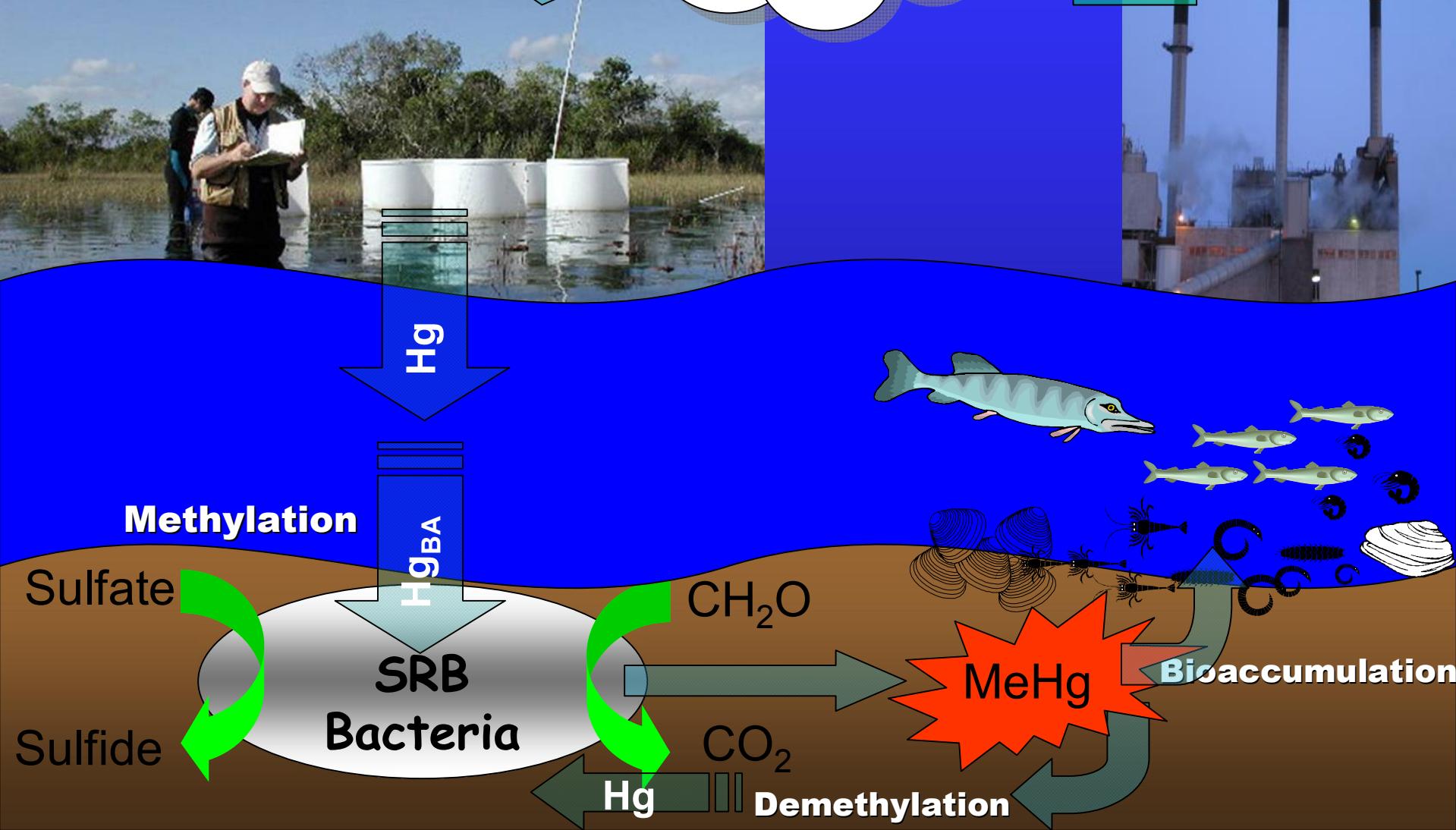
Yellowstone NP, USA

# The Mercury Cycle

Deposition



Emissions



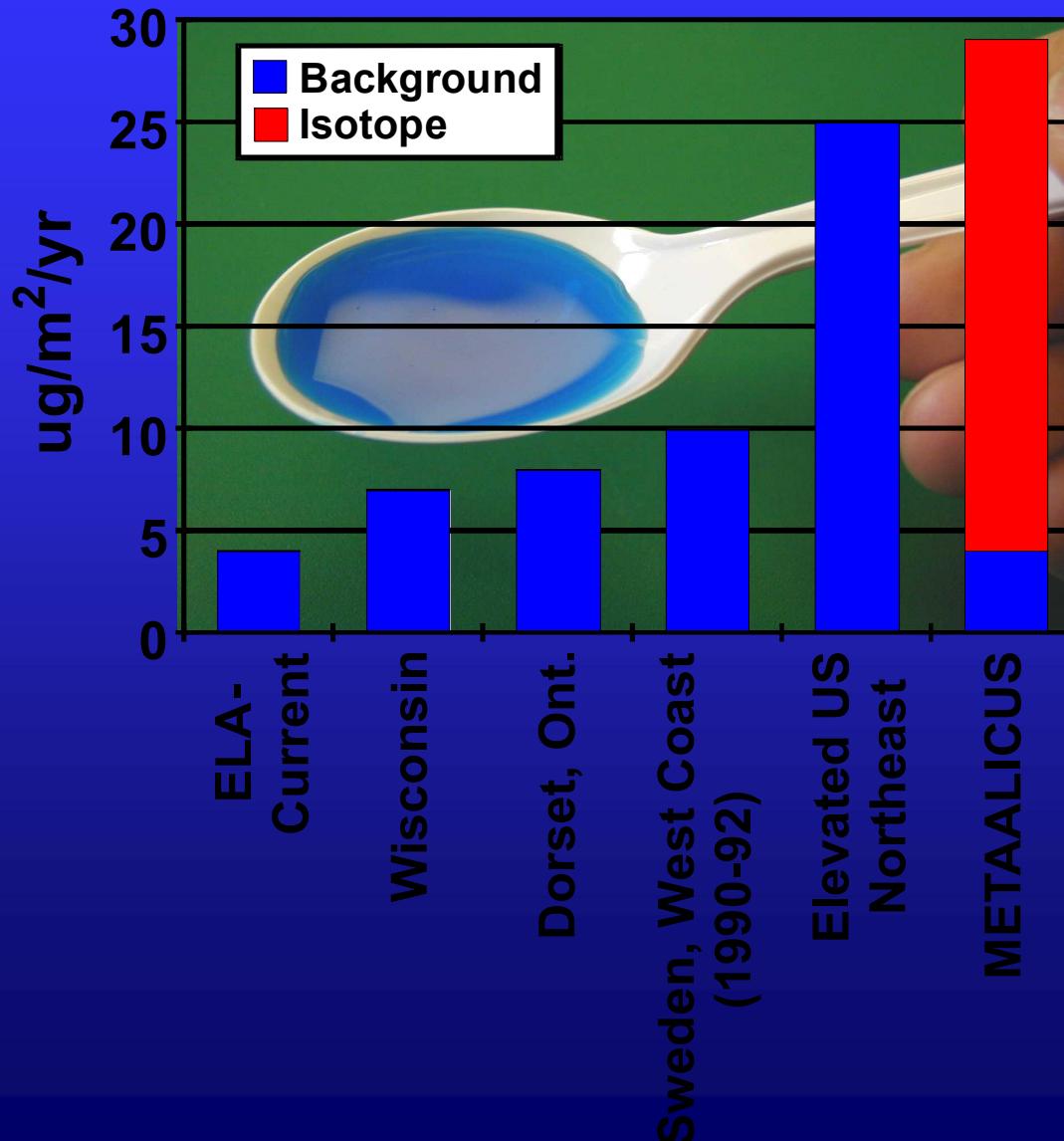
How important  
are mercury load  
reductions, if the  
whole planet is  
already  
contaminated?



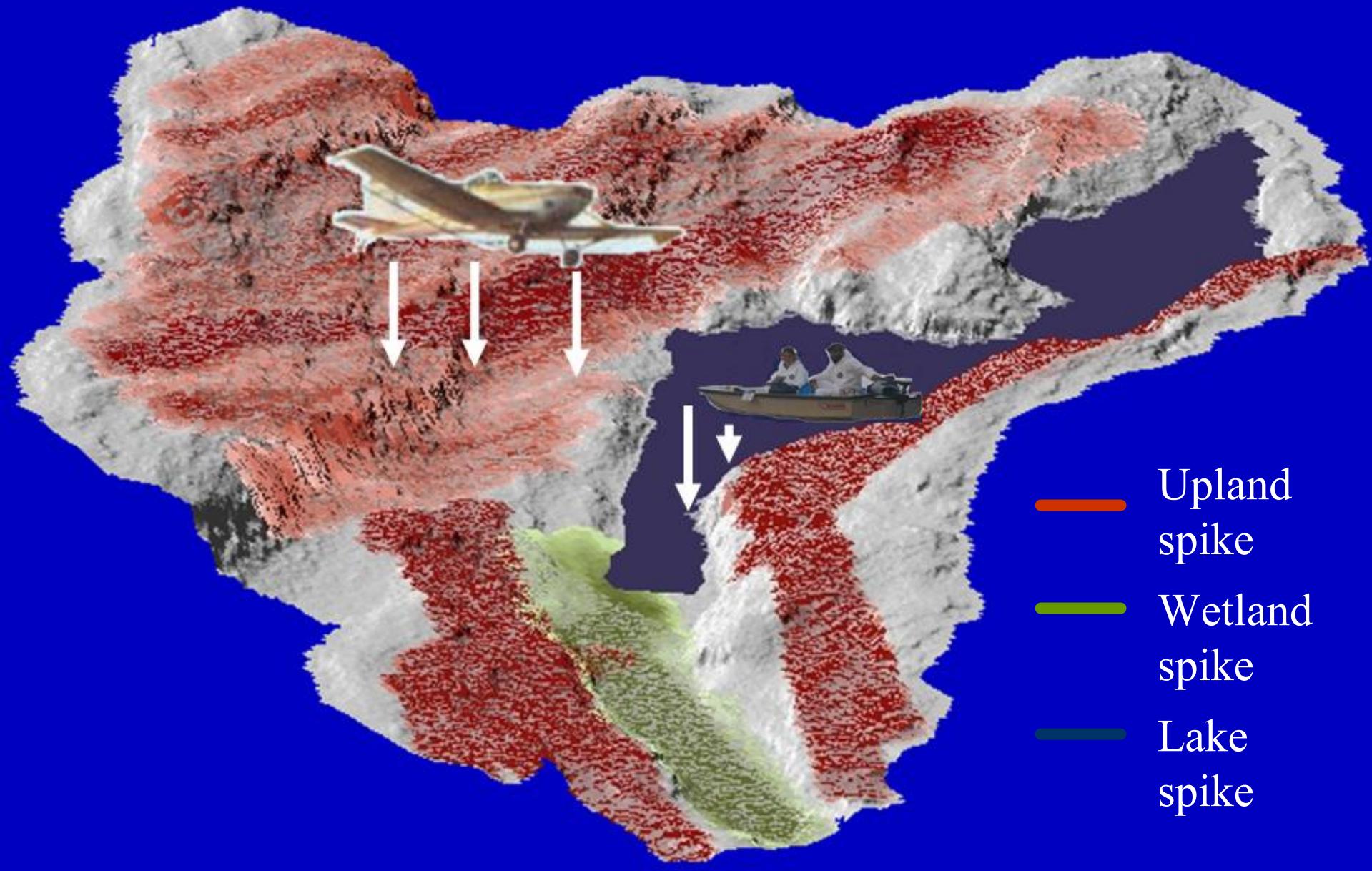


Mercury Experiment to Assess  
Atmospheric  
Loadings In Canada and the  
United States

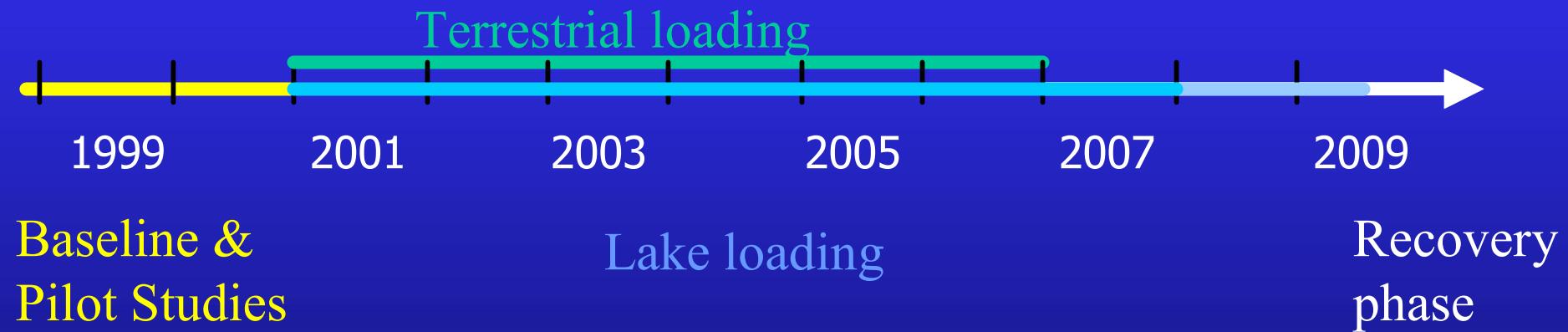
# How much mercury are we adding?



Hg is applied each year by plane and boat..

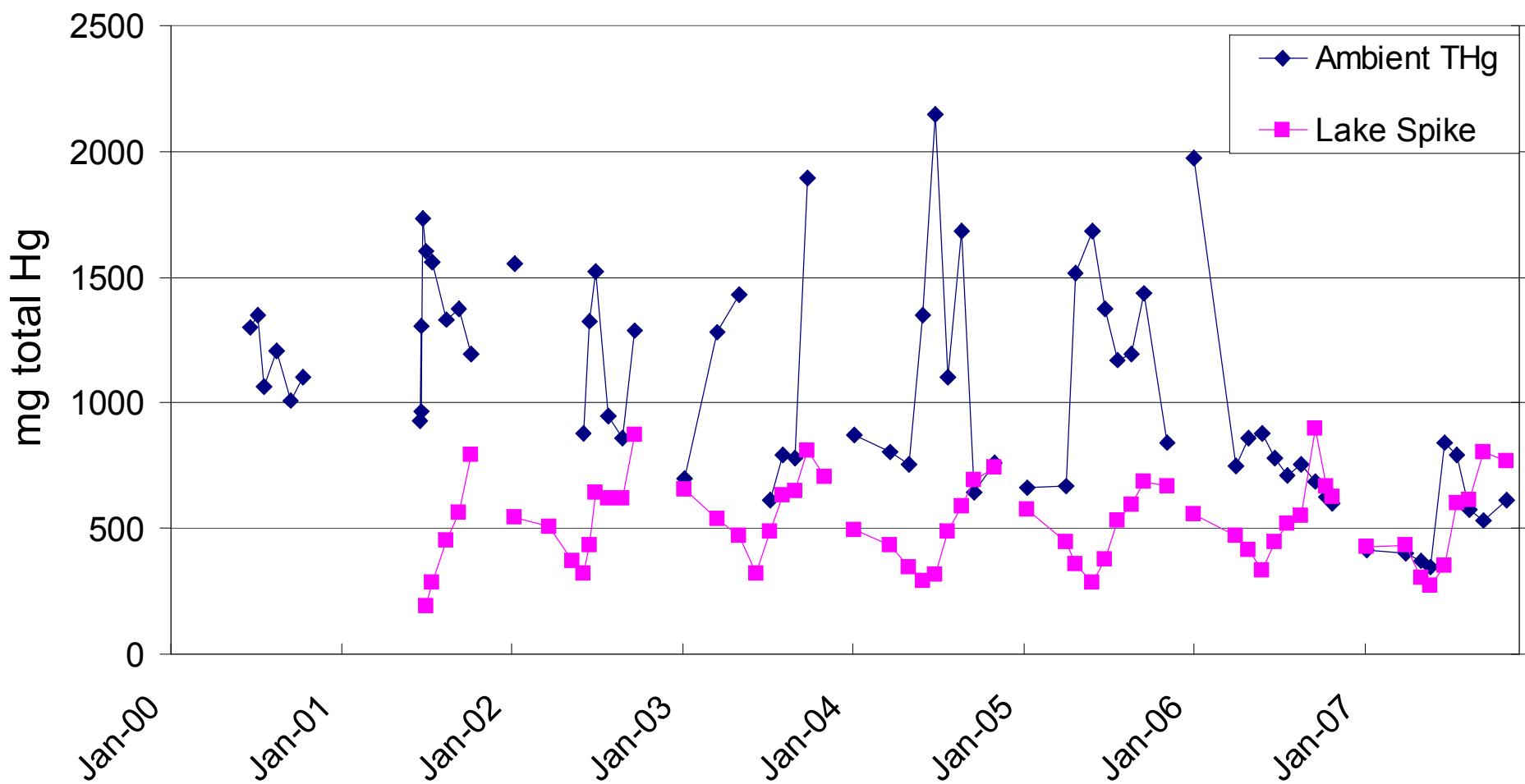


# METAALICUS Schedule

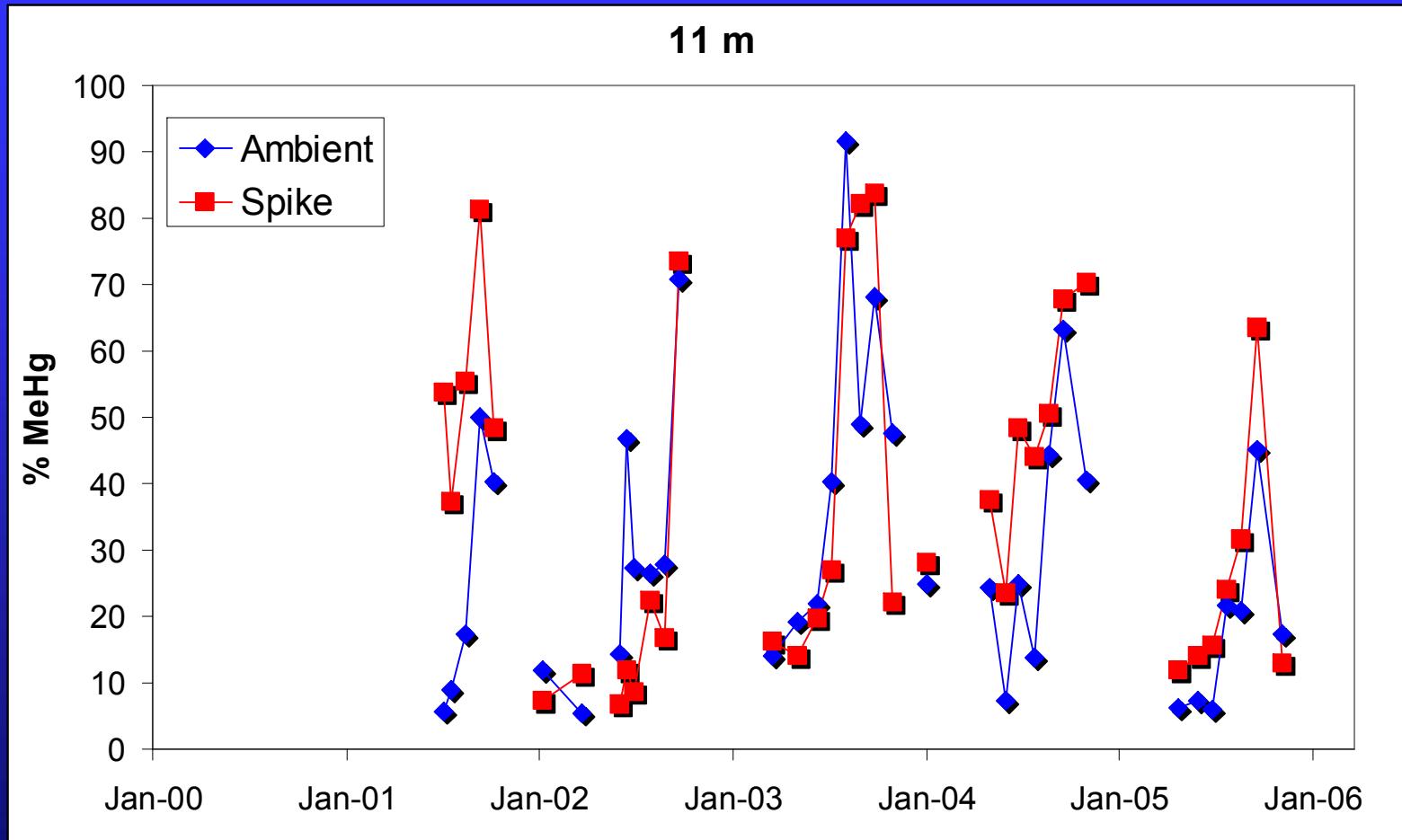


# How did the lake respond?

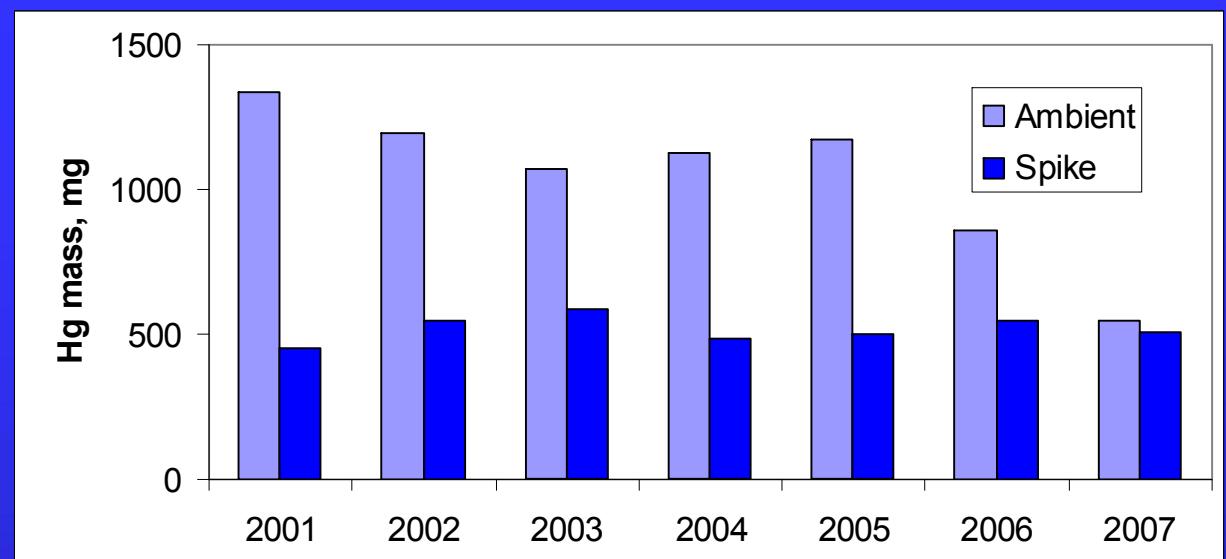
## Total Hg mass, water column



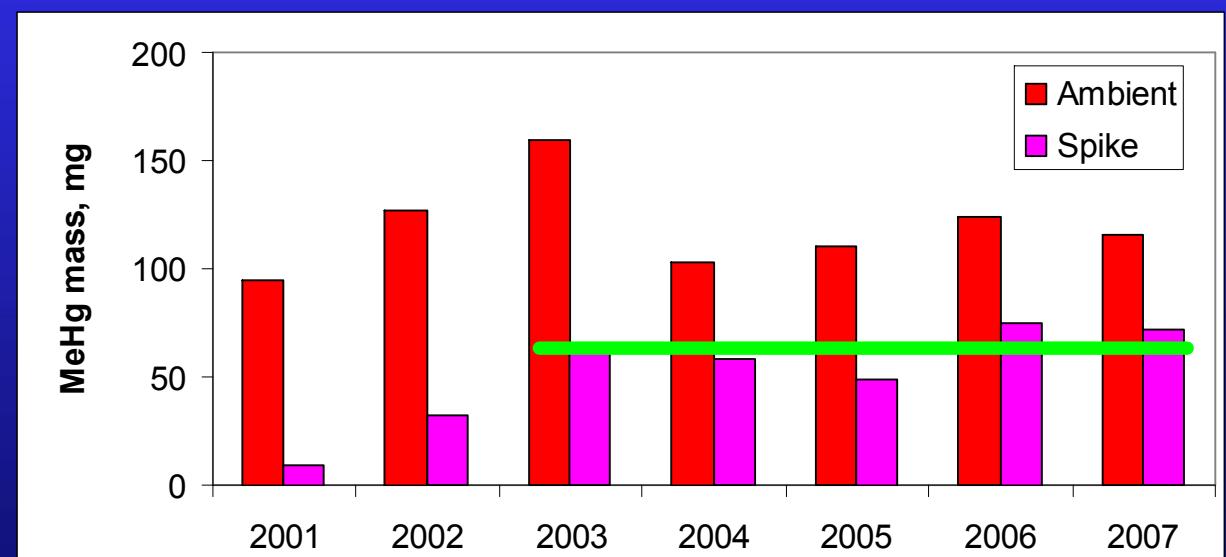
# Spike and Ambient Hg are methylated equally in the water column



## Annual average mass of Hg in L658 water column



## Annual average mass of MeHg in L658 water column



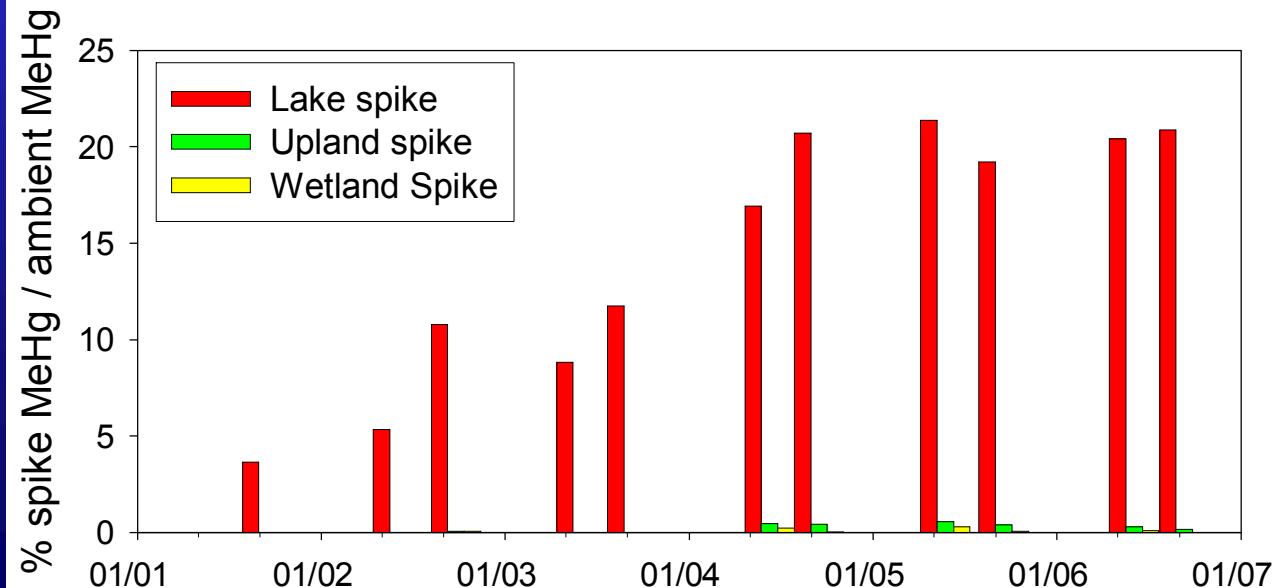
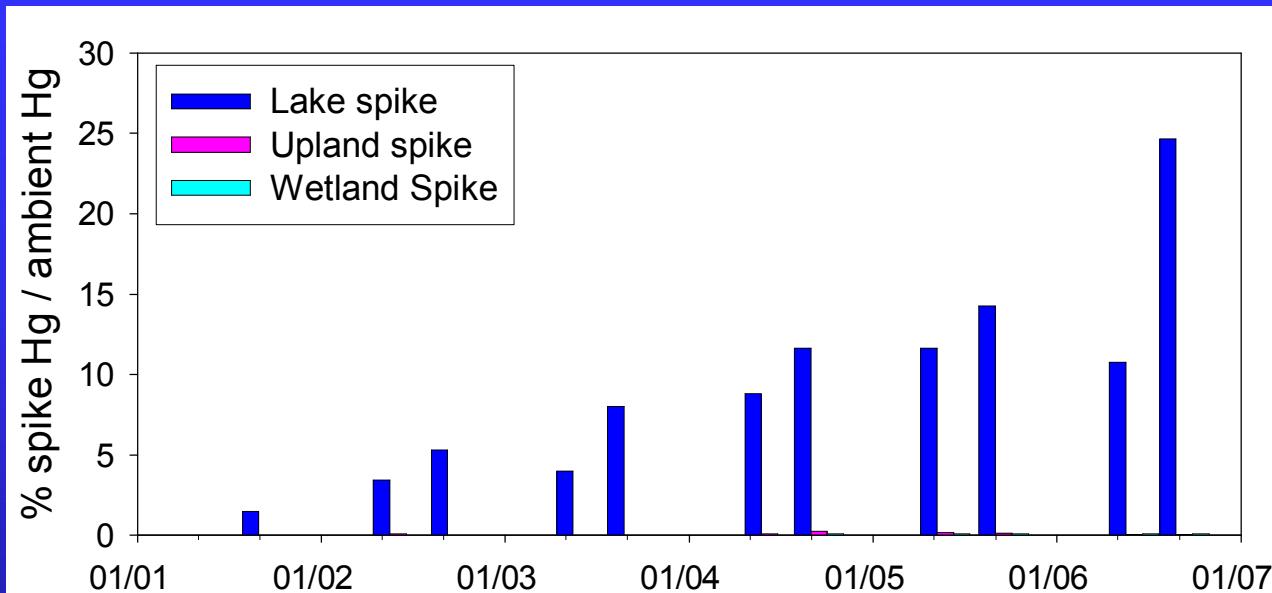
Equilibrium after 3 years?

# How did sediments respond?

Increase in sediment Hg due to spike



Increase in sediment MeHg due to spike



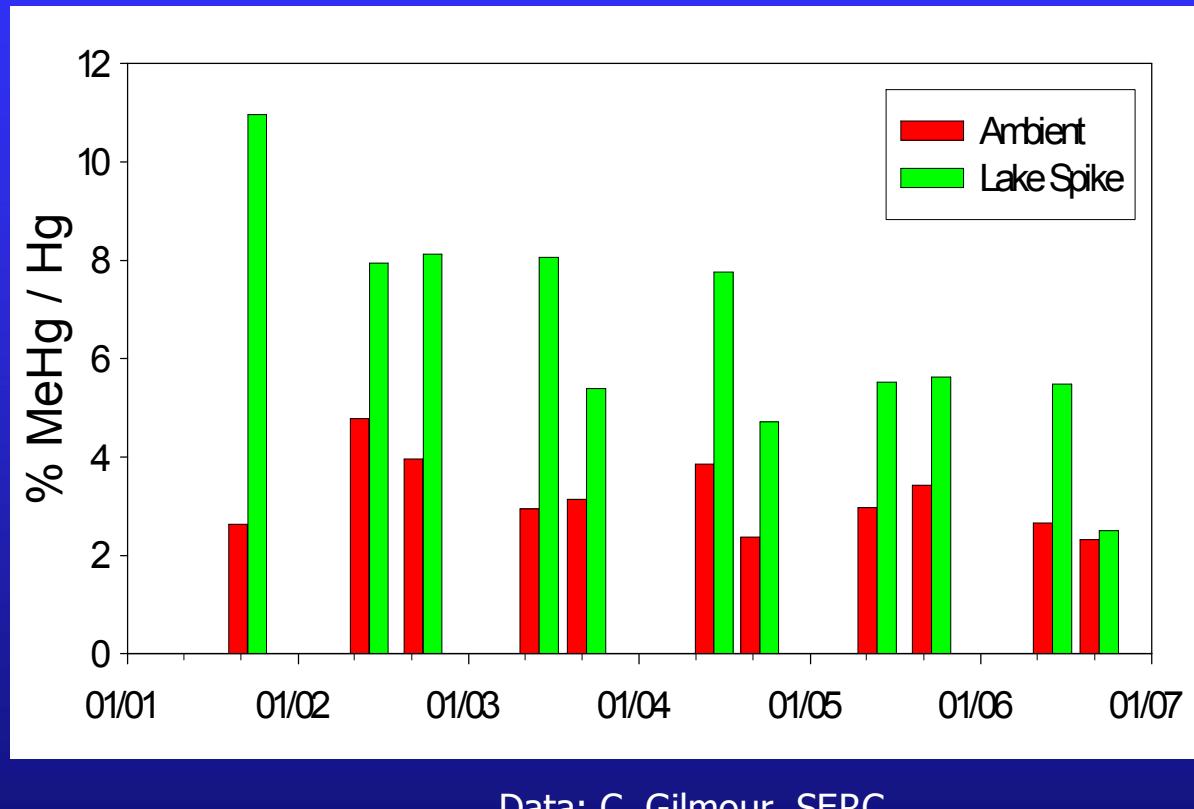
# Bioavailability of sediment Hg for methylation

%MeHg/Hg

=

Net production of MeHg from inorganic Hg

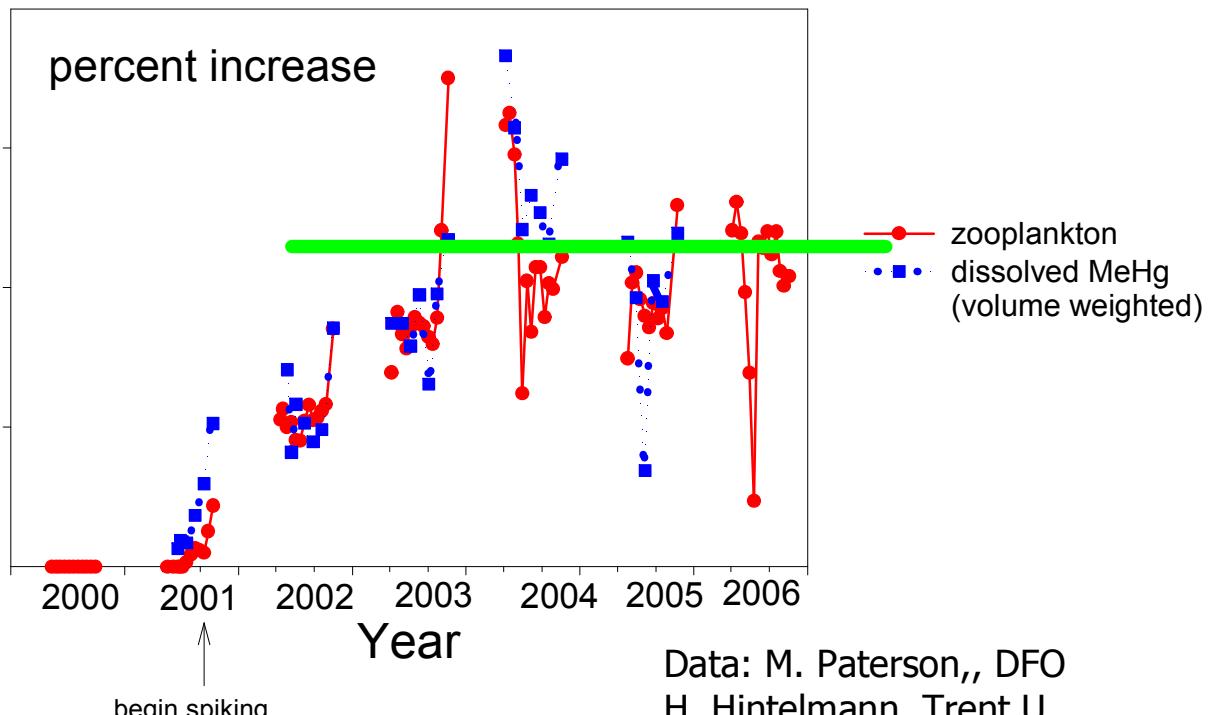
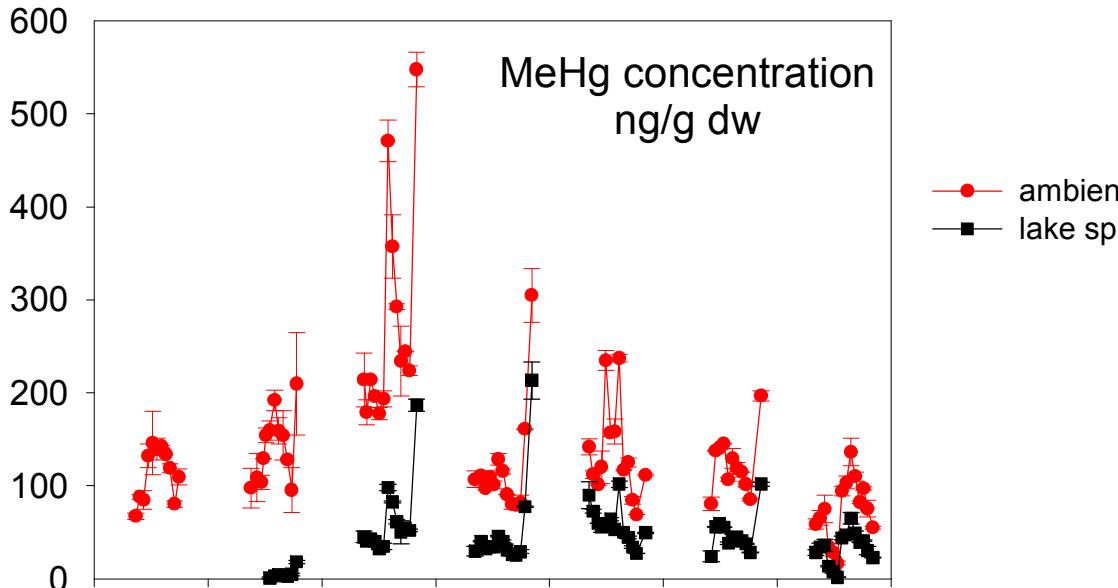
As the lake spike aged in sediments, a smaller and smaller fraction was found as MeHg.



Data: C. Gilmour, SERC

Bioavailability of lake spike Hg is now similar to ambient Hg

# Zooplankton



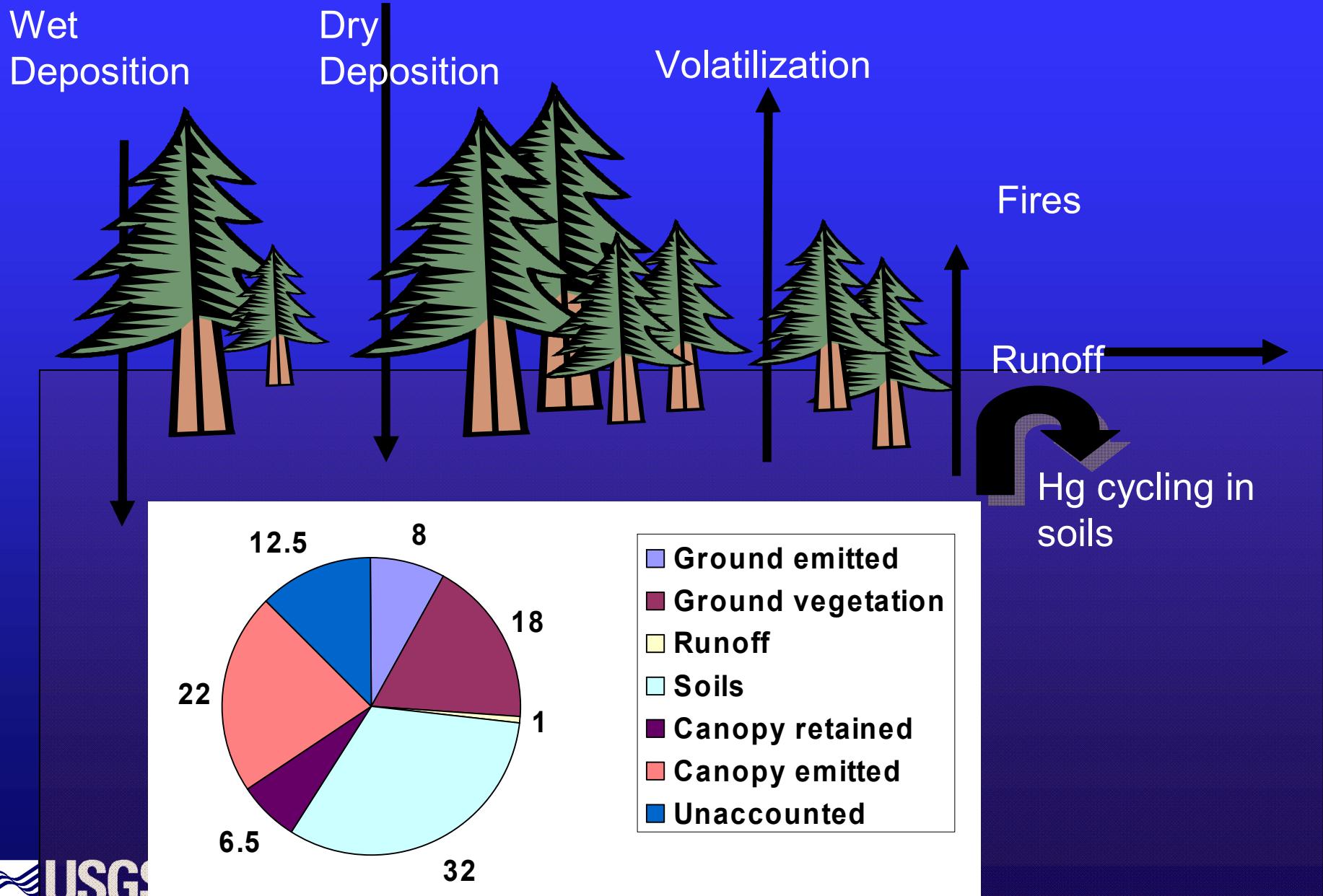
Data: M. Paterson,, DFO  
H. Hintelmann, Trent U.



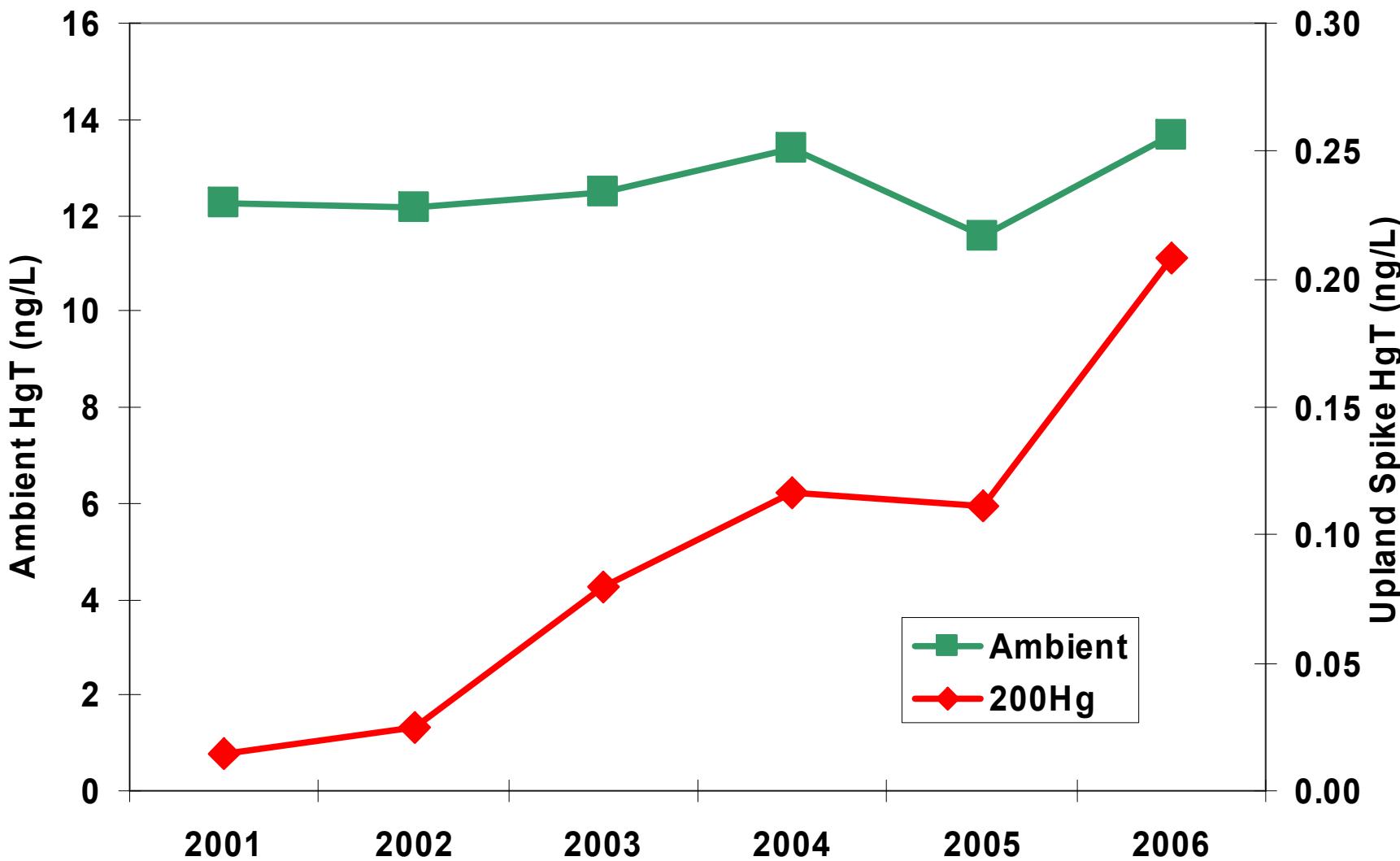
# Fate of $^{200}\text{Hg}$ deposited to the upland



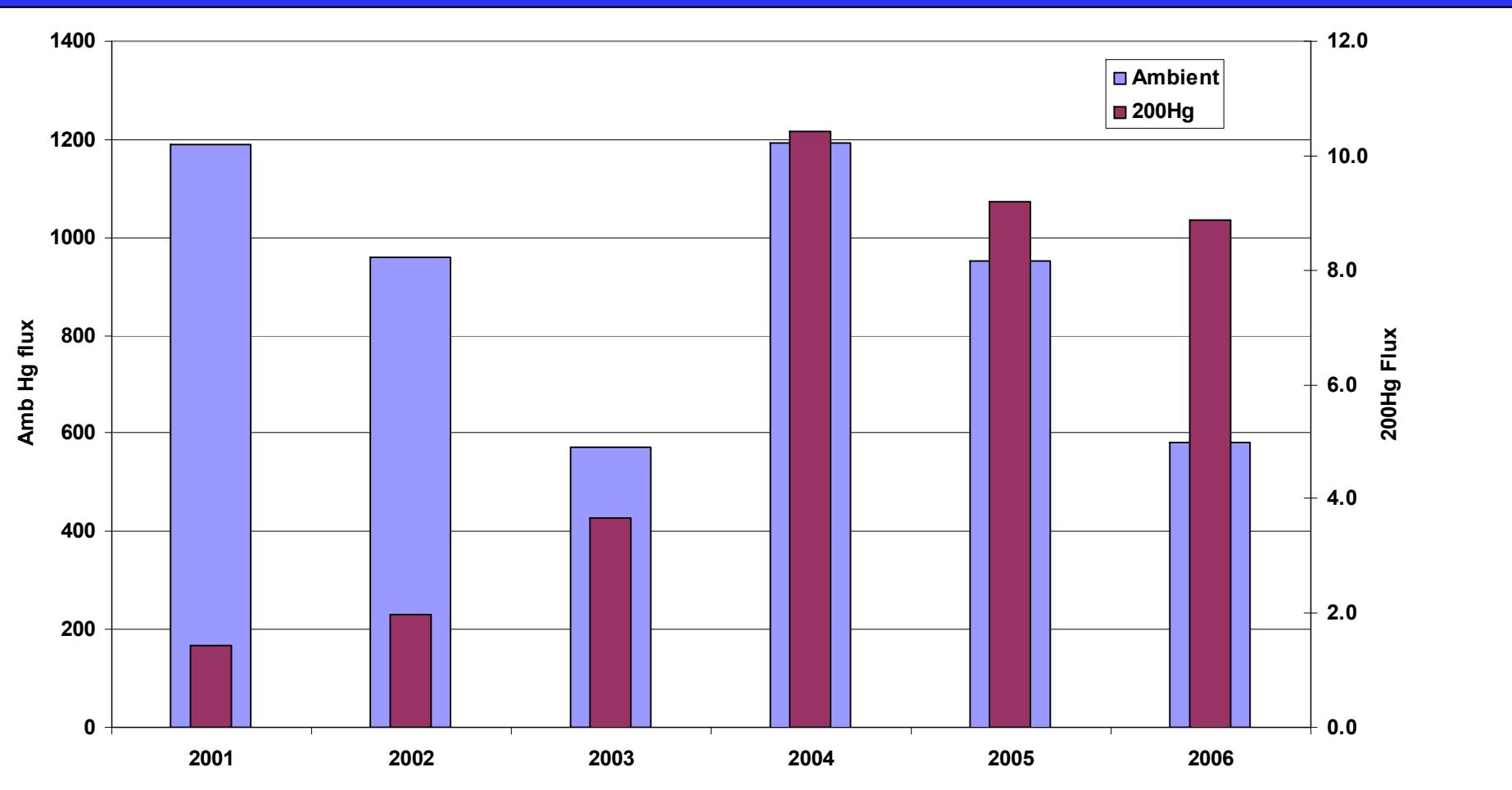
# Conceptual Diagram of a Terrestrial Hg Mass-Balance Model



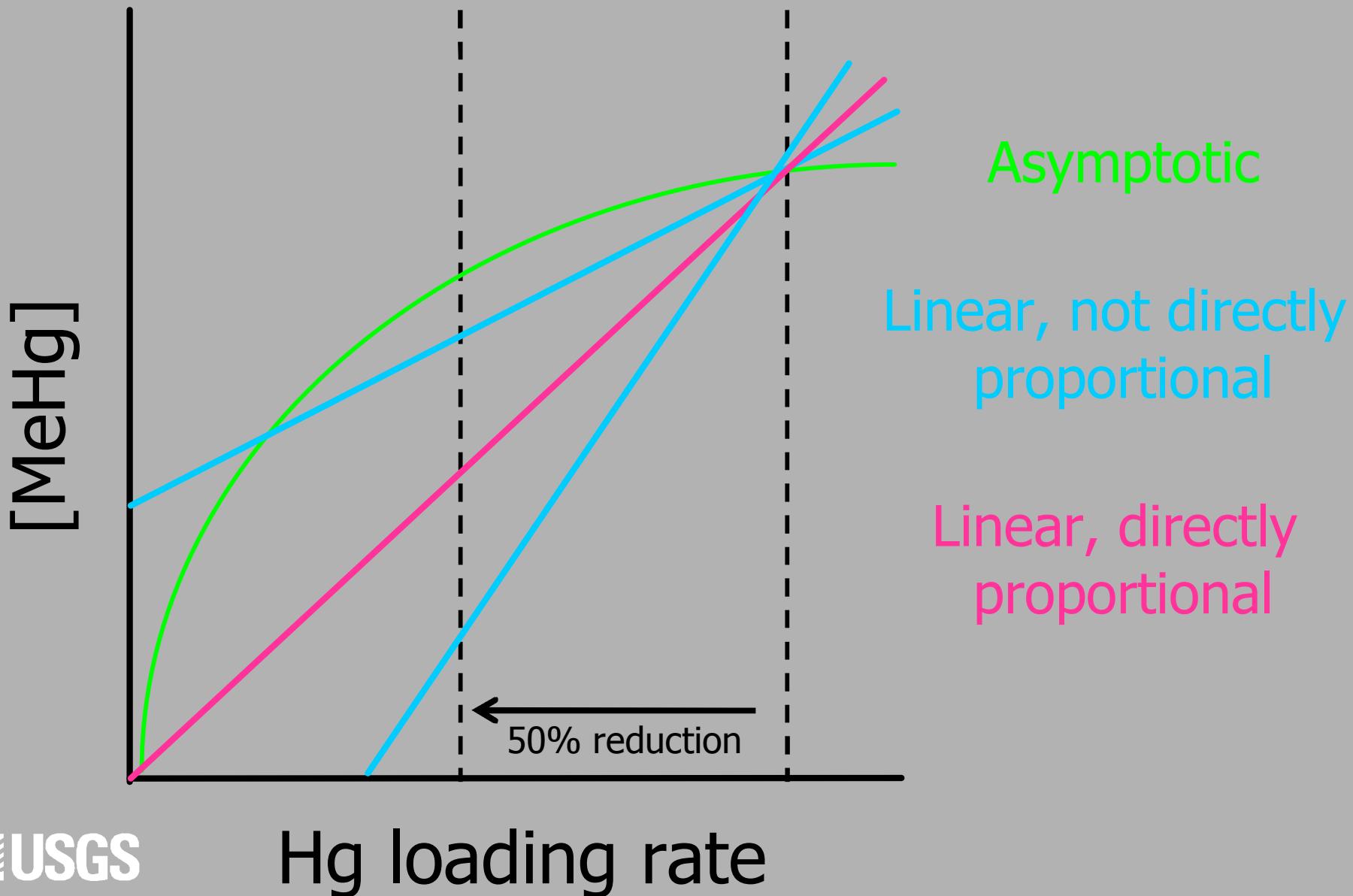
# Times Series for Ambient and Upland Spike THg in Runoff from the METAALICUS Study Watershed



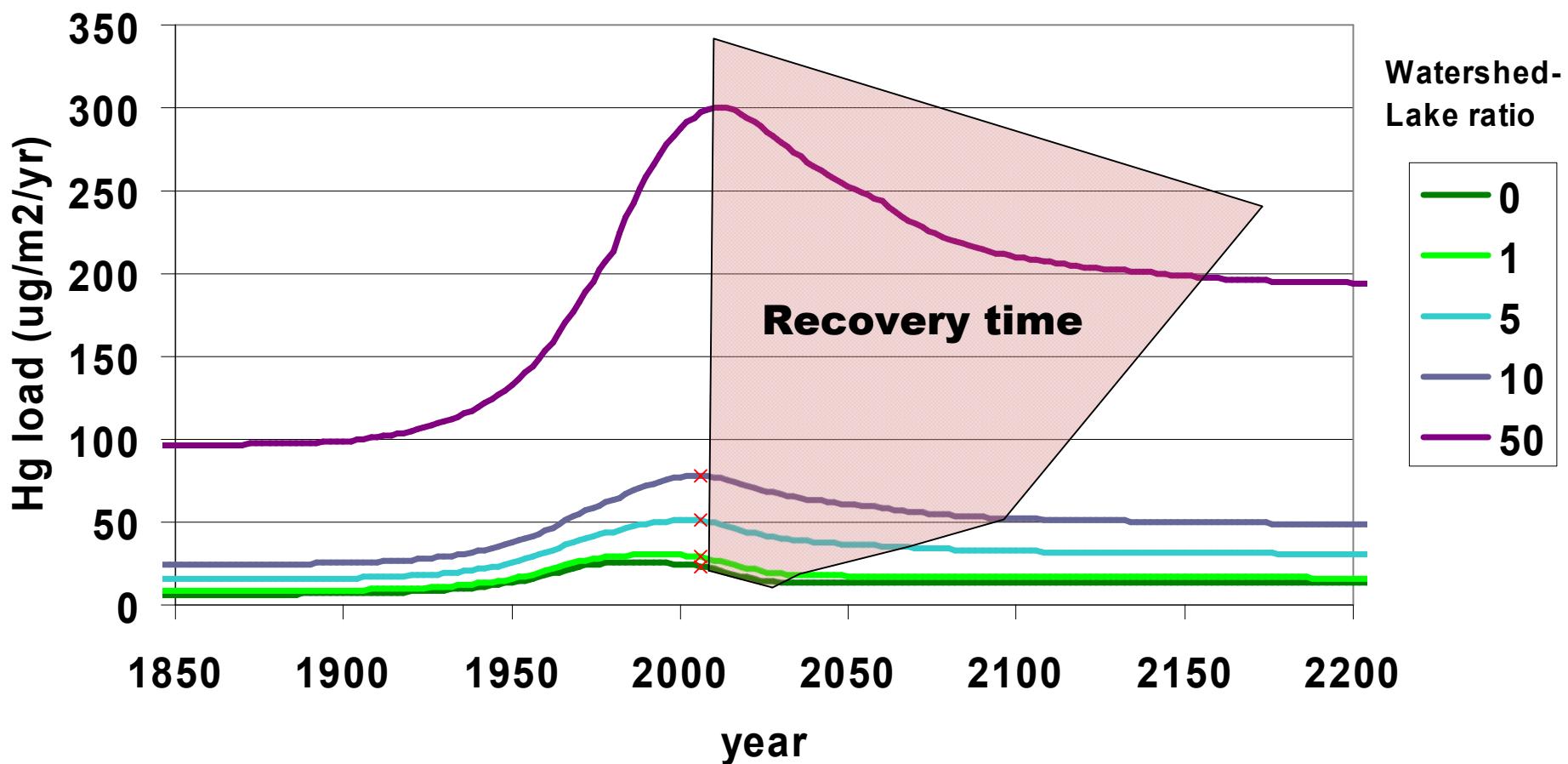
# Mercury Fluxes from the Upland 2001-2006 (mg)



# Understanding the Response to a Decrease is Equally (or more) Important



# Recovery Time Estimates for Various Watershed-Lake Area Ratios



# Summary:

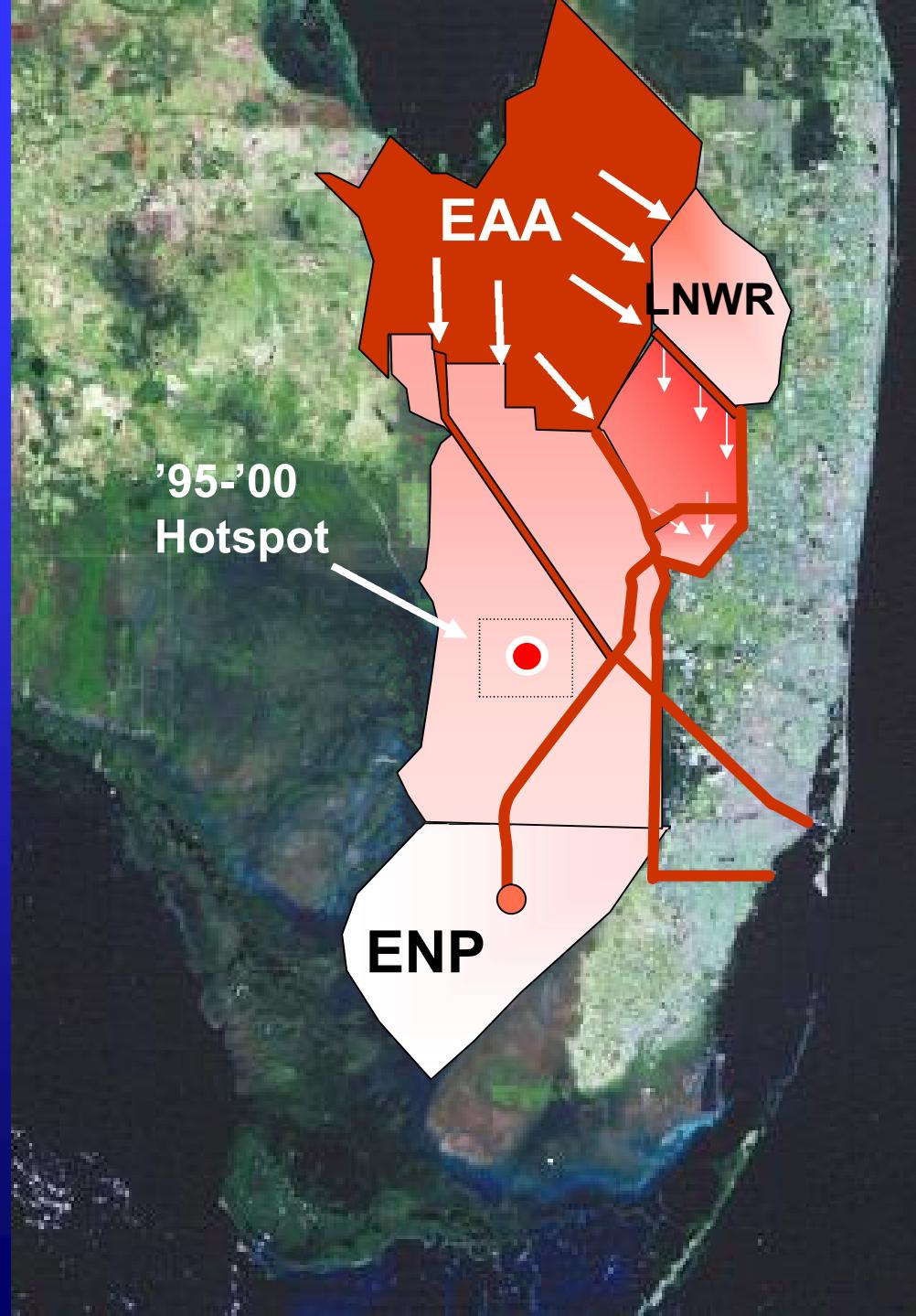
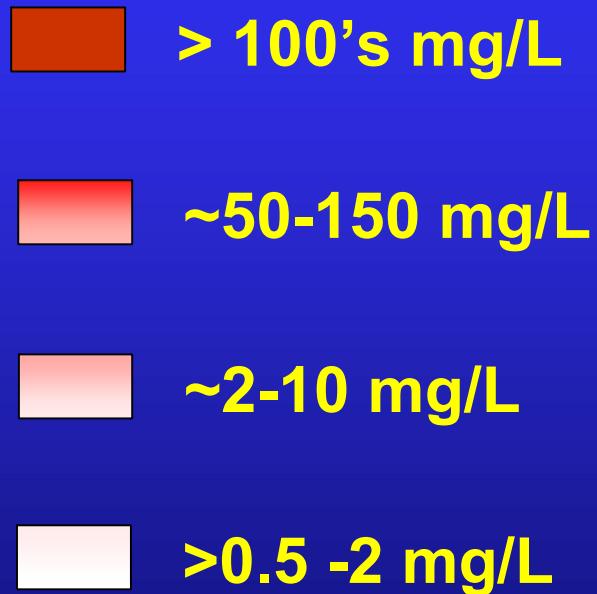
- Relative contributions of Hg from watersheds will be a principal key in determining the recovery (response) times, ranging from 10-100's of years
- Recovery will be two phase: quick response to changes in direct deposition, much longer for watershed Hg
- After seven years of loading, it appears watershed Hg in more bioavailable
- Mass accounting of Hg in the lake and the watershed lends insights into dominant accumulation points and recycling.



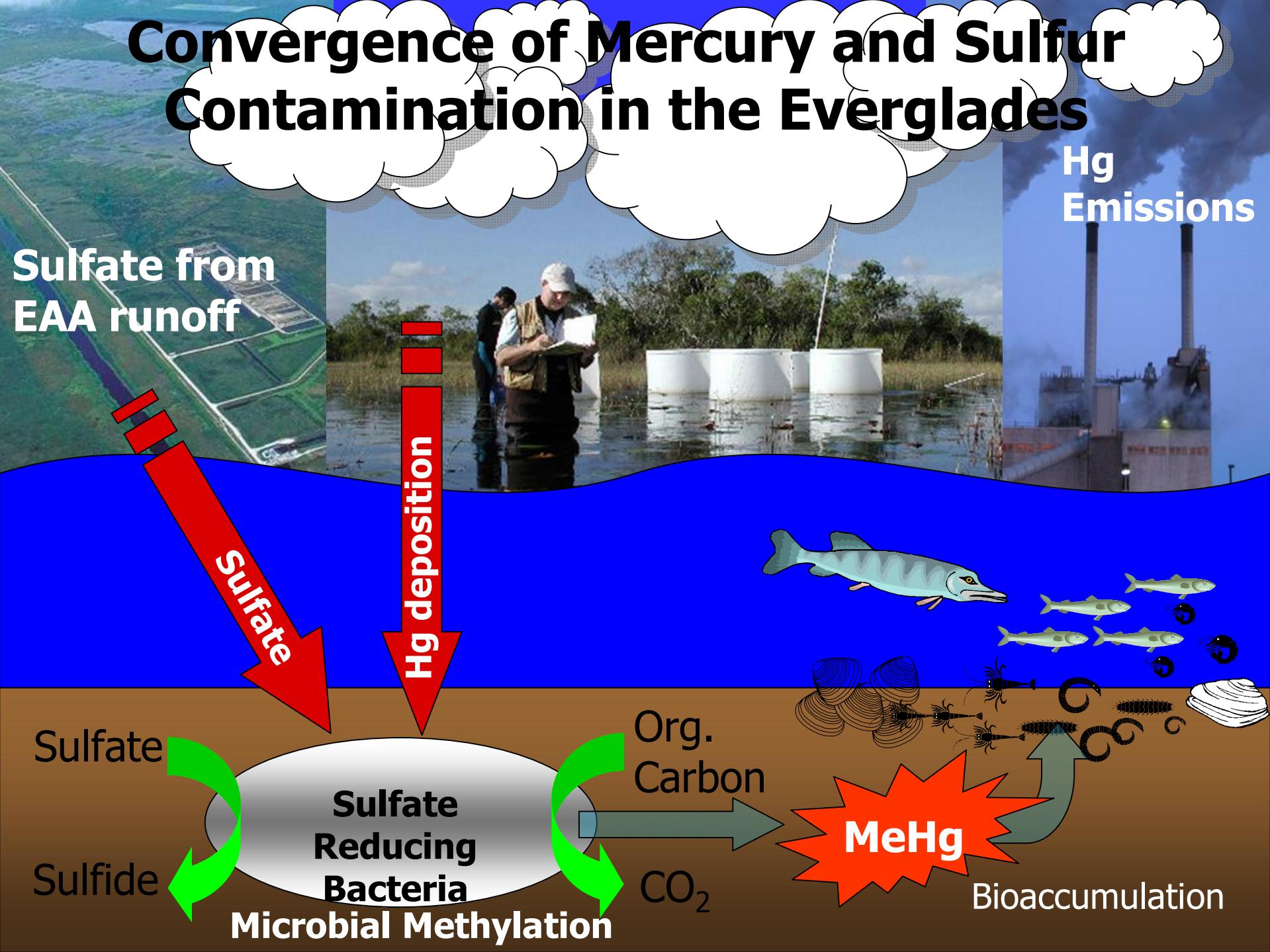
Runoff at the Lake 658 -  
METAALICUS study site

# The Everglades & Mercury

## Extent of Sulfate Contamination in the Everglades



# Convergence of Mercury and Sulfur Contamination in the Everglades



# Mercury Axis of Evil



Sulfur

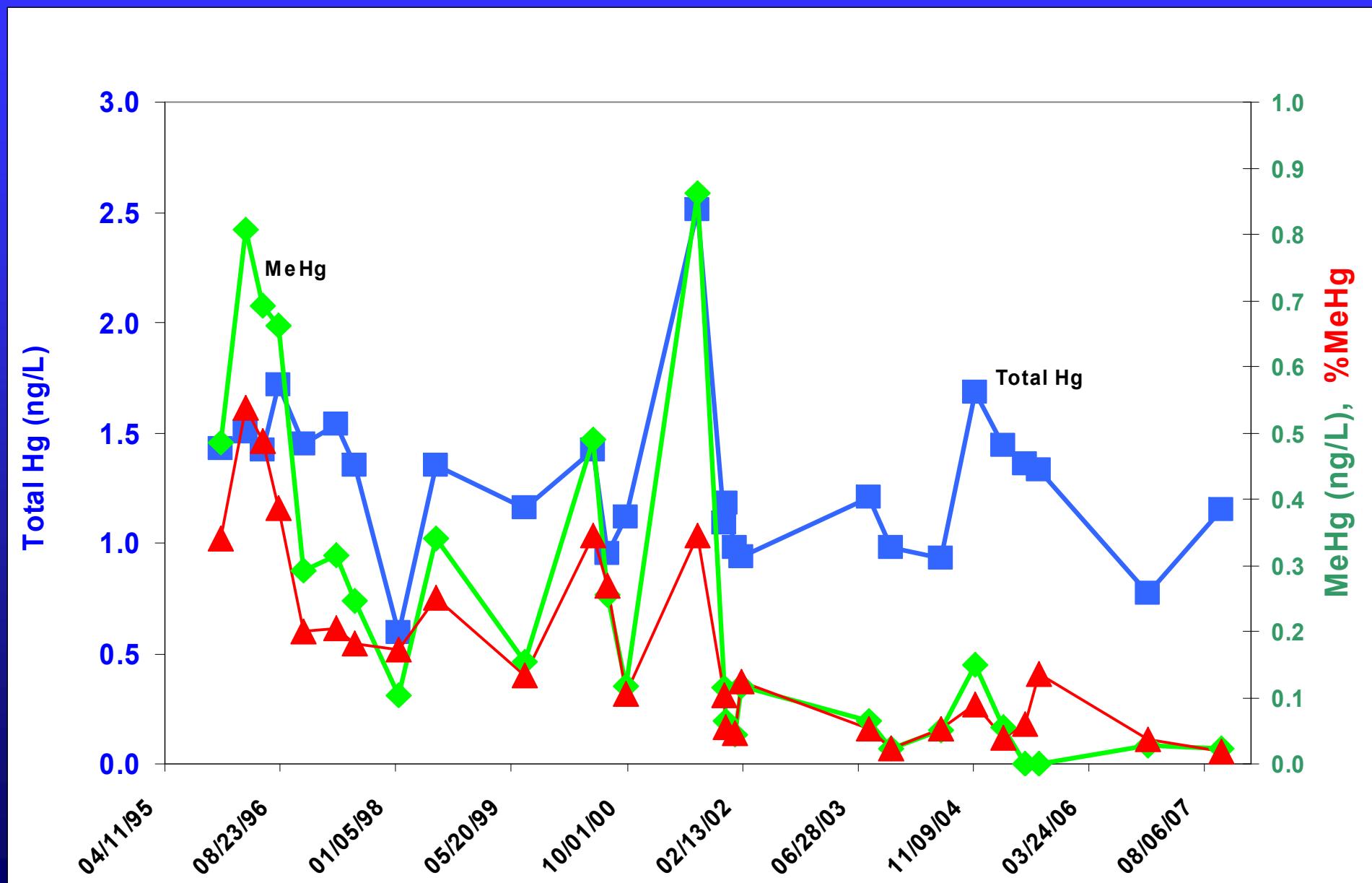


Mercury

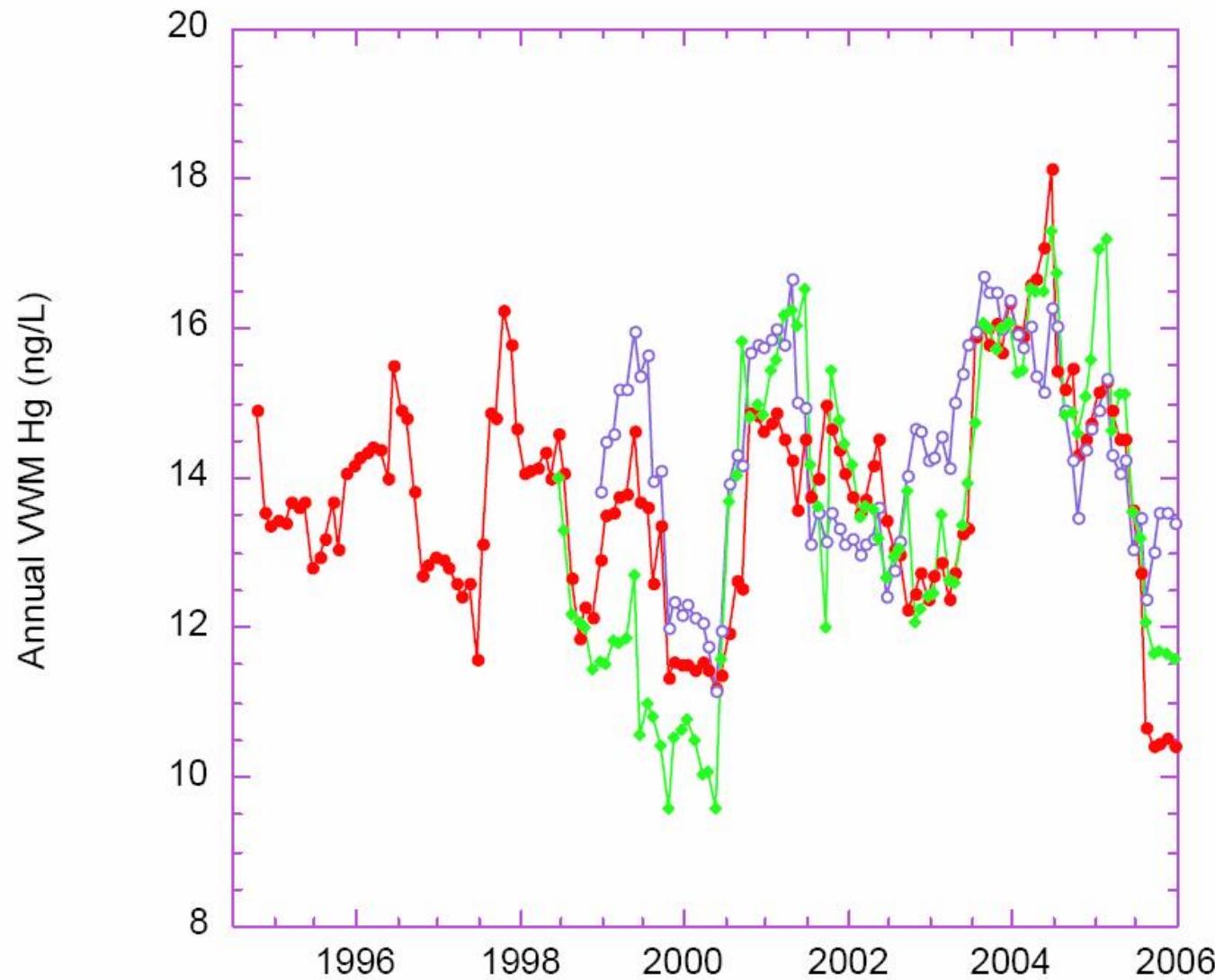


Carbon

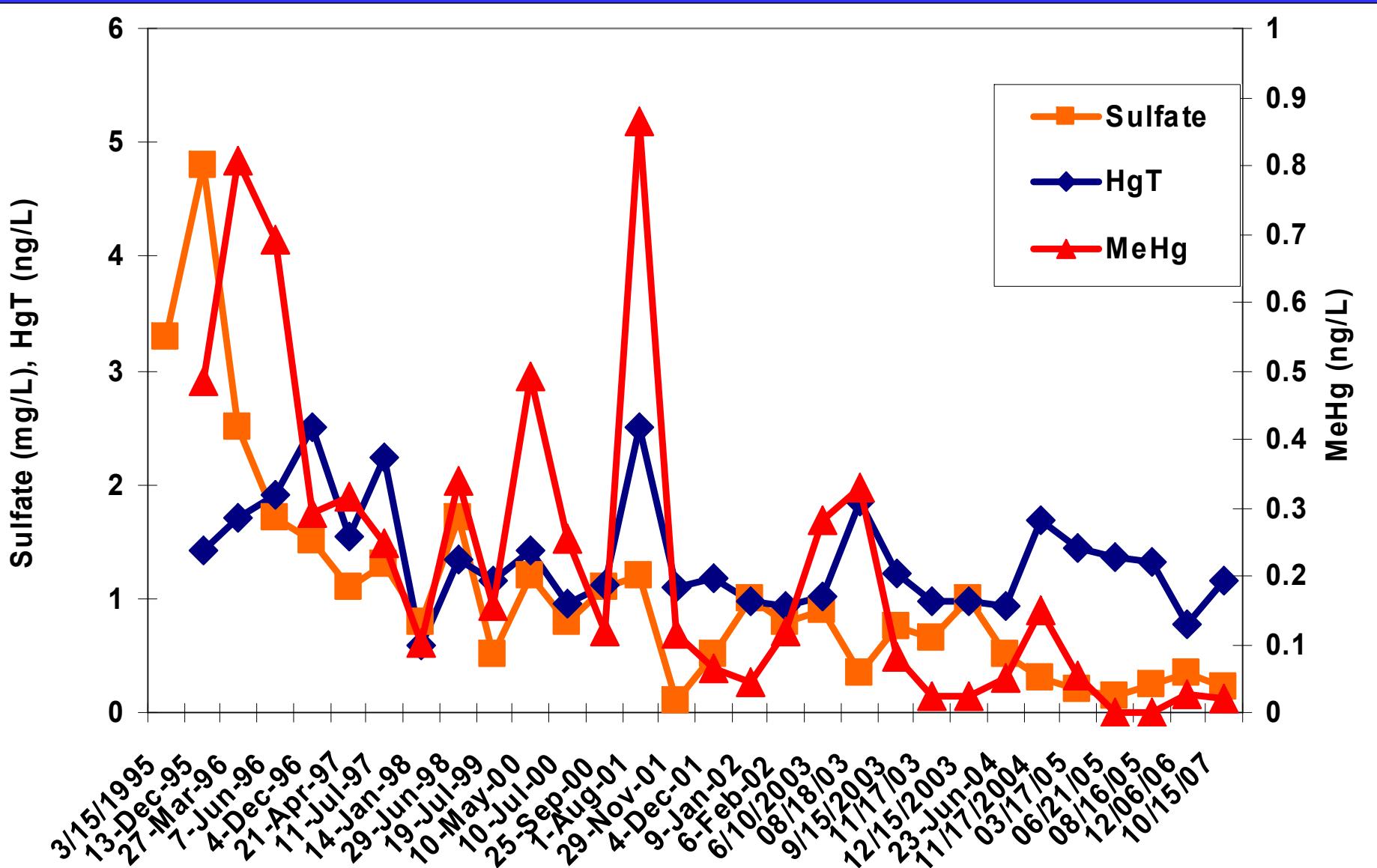
# Everglades Hg & MeHg Time Series



# Time Series for Mercury Deposition in South Florida 1993-06



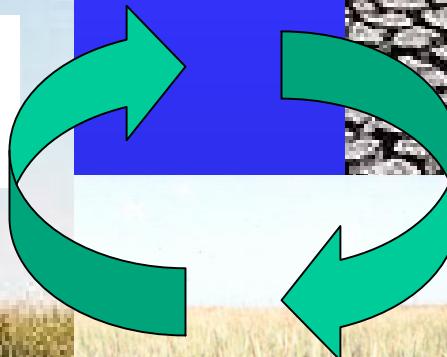
# $\text{SO}_4$ , MeHg & HgT Time Series



But, then the Everglades dried up in 1999



Bioaccumulation &  
wet cycle period

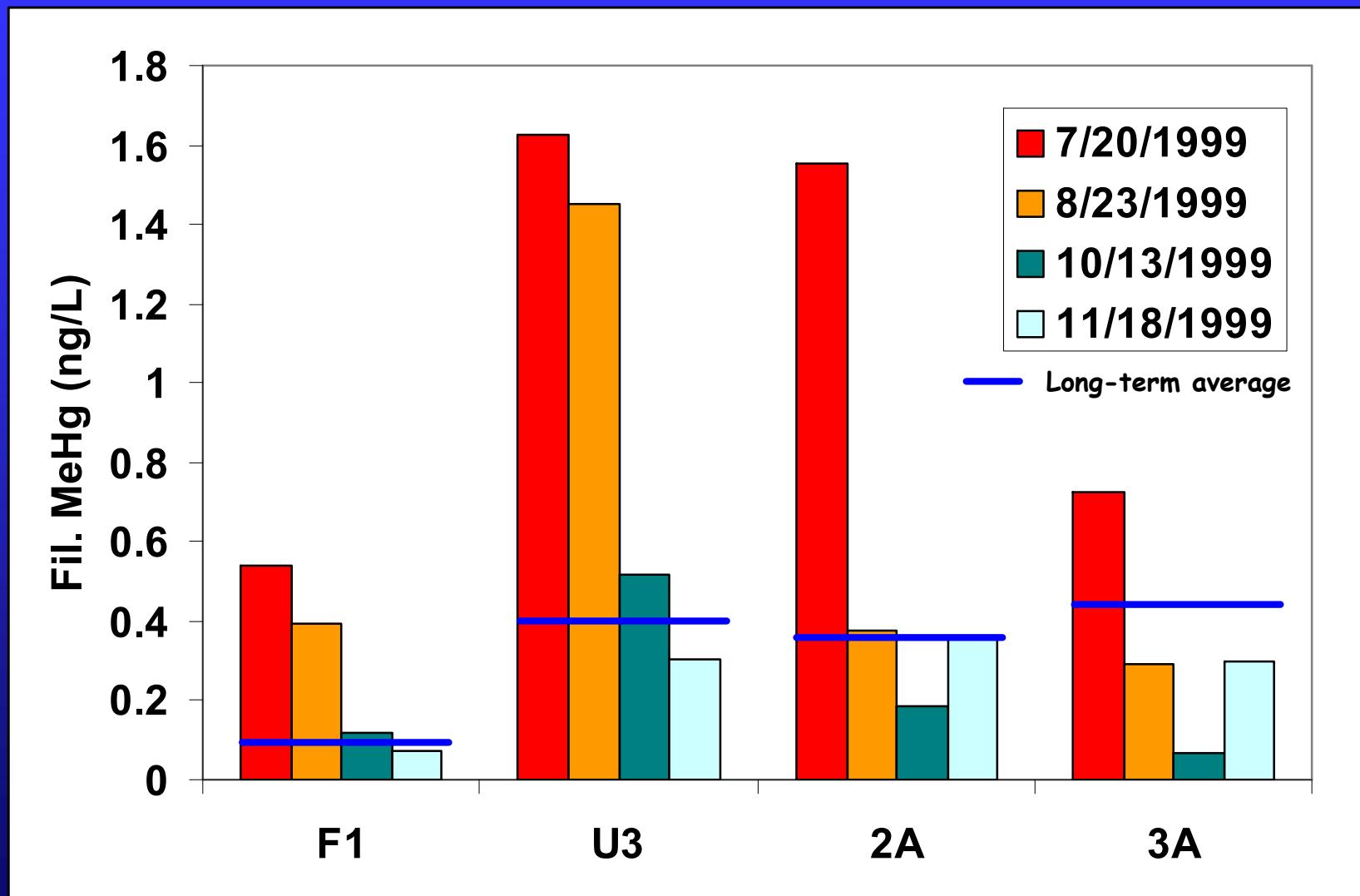


Dry down &  
oxidation

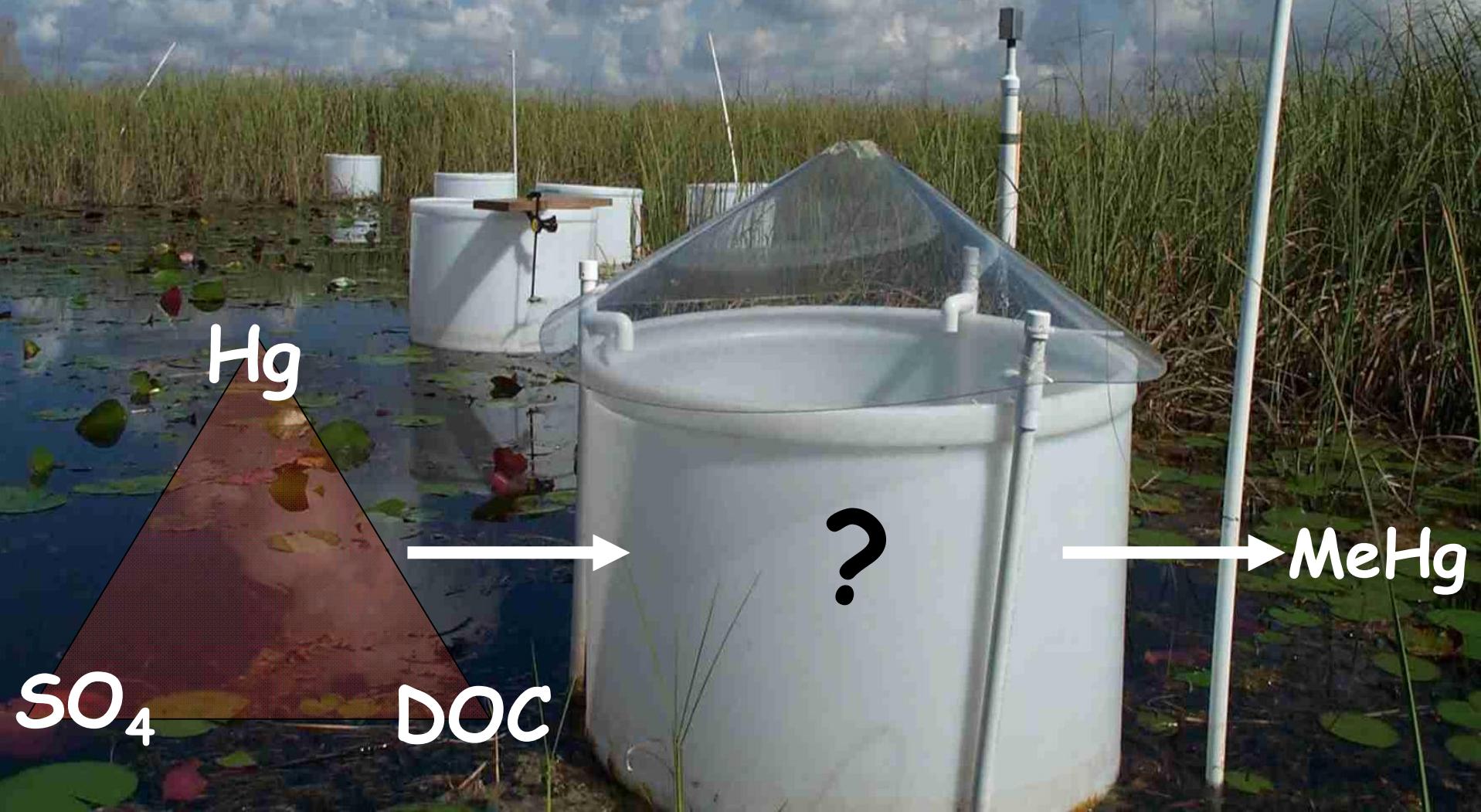
Rewetting &  
methylation



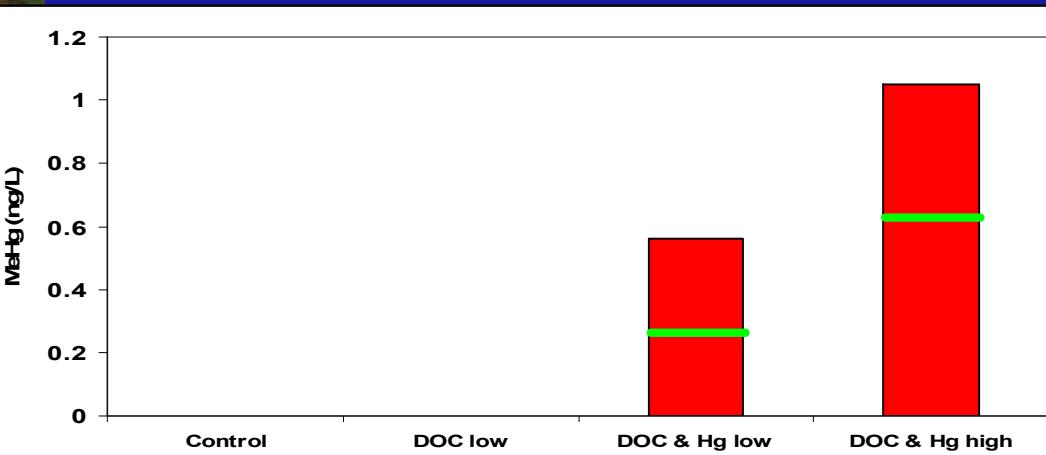
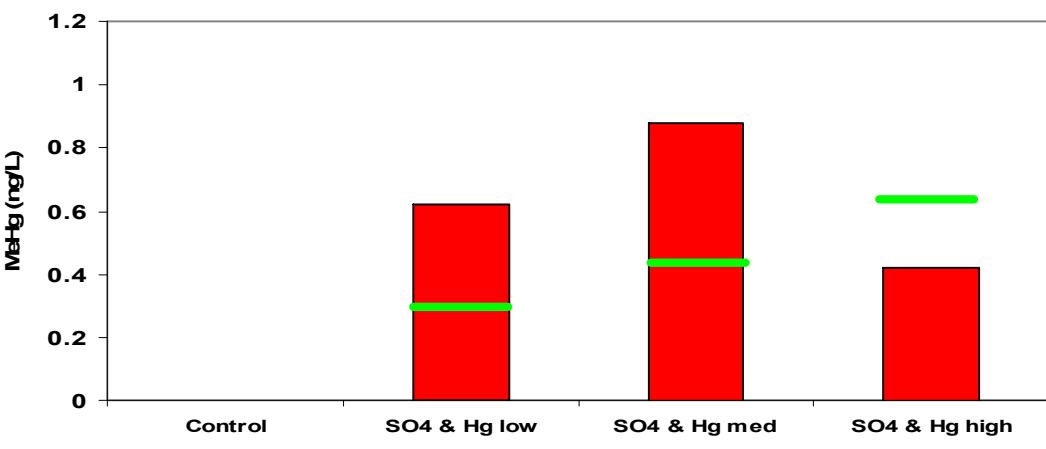
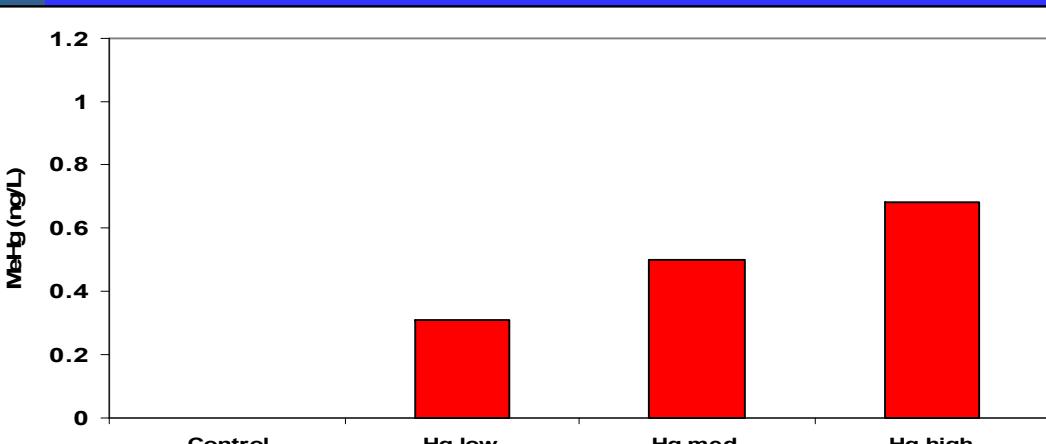
# Hydro-Cycle Punctuated MeHg Production



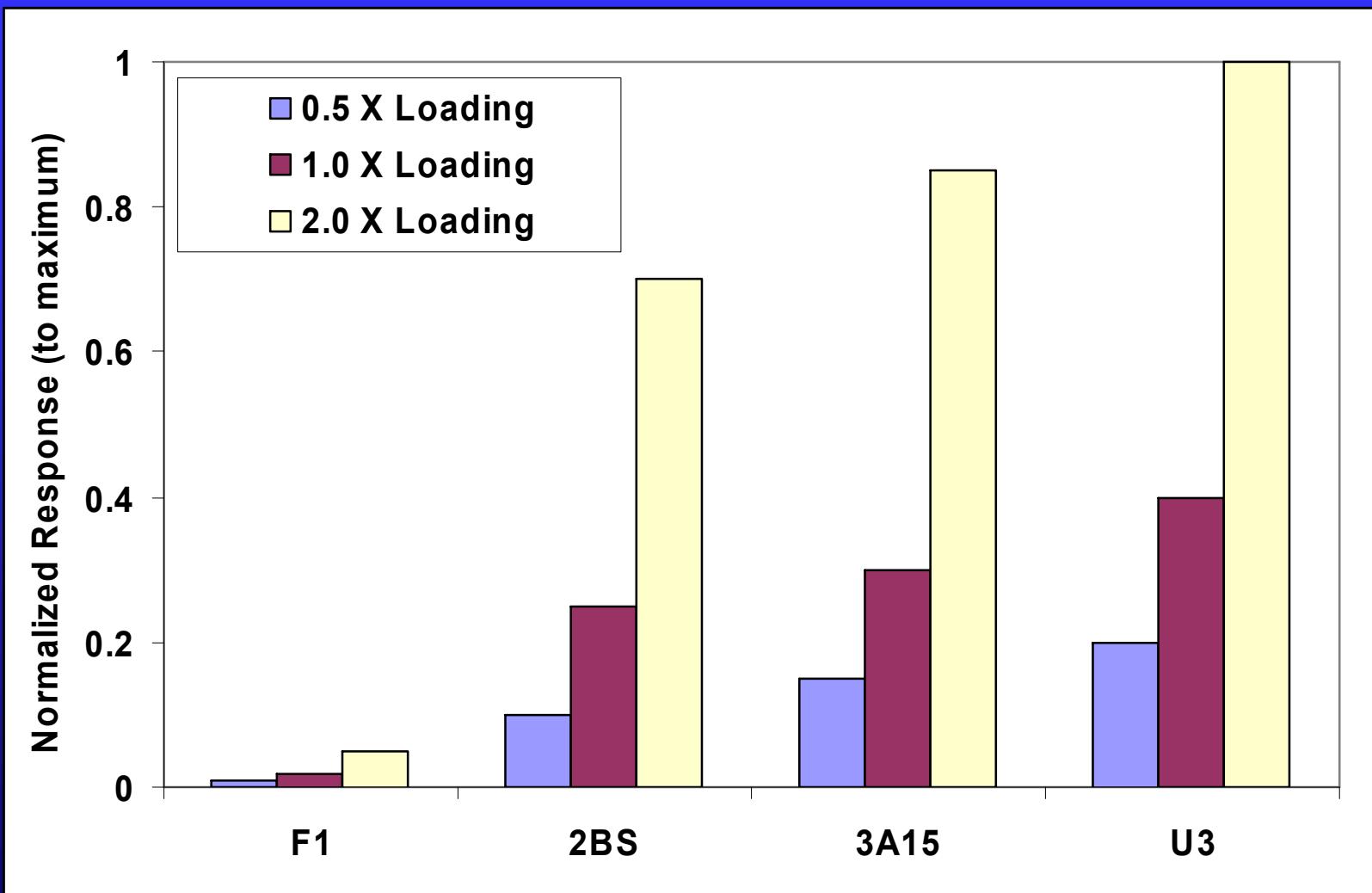
# What's driving long-term MeHg levels in the Everglades?



# Production of $\text{Me}^{201}\text{Hg}$

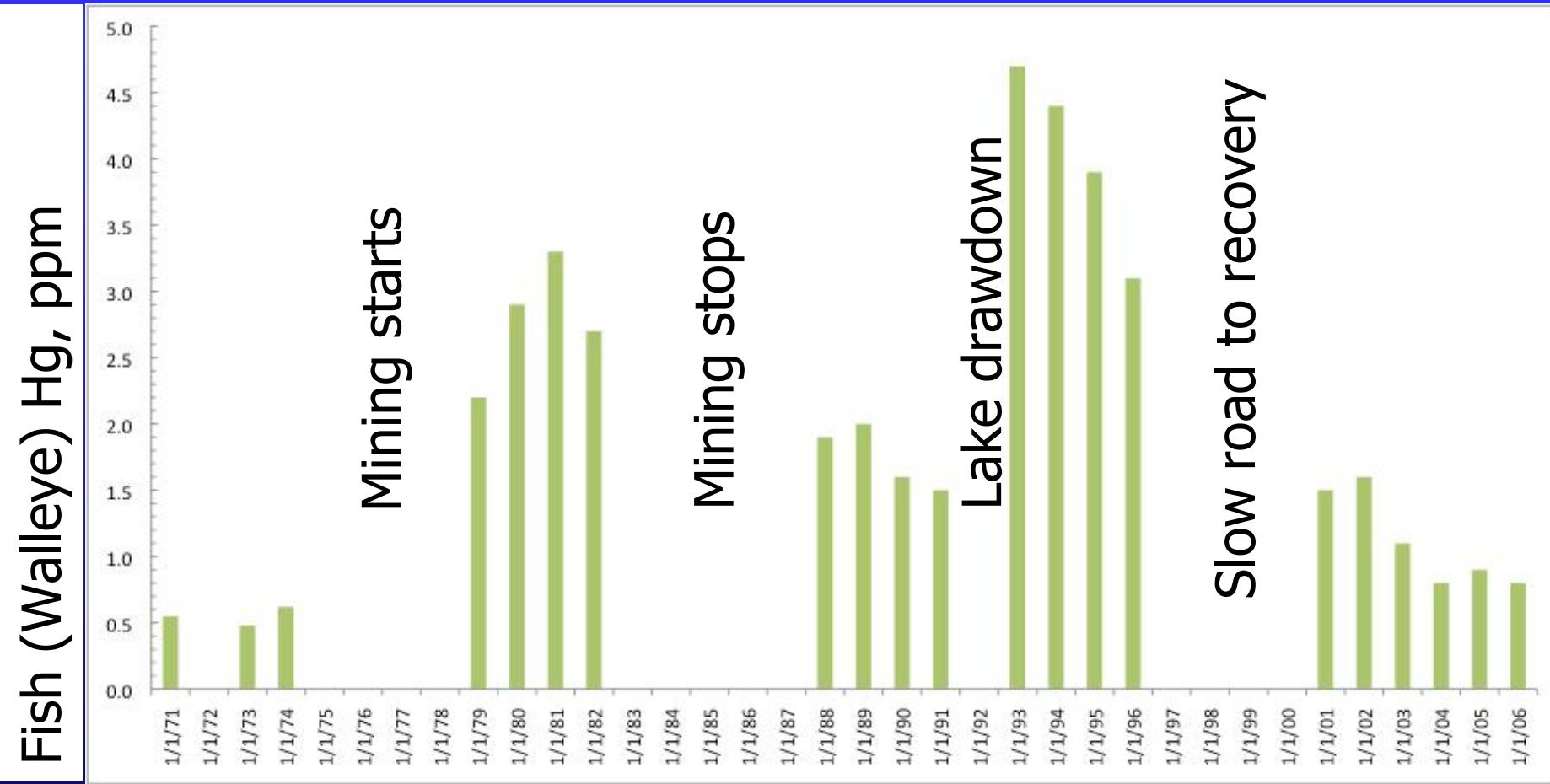


# Multi-Site Dose Responses



# Reservoirs and Management

## Example from Deer Lake, MI



## 2007 USEPA National Lakes Survey:

- 909 lakes across the coterminous US
- Status of the nations lakes using indicators of indicators of trophic state, ecological health, and recreation
- Provide information on key stressors: nutrients and pathogens (and contaminants)
- Probability-based network to represent conditions of all USGS lakes across each region



# 2007 USEPA National Lakes Survey Sampling Sites

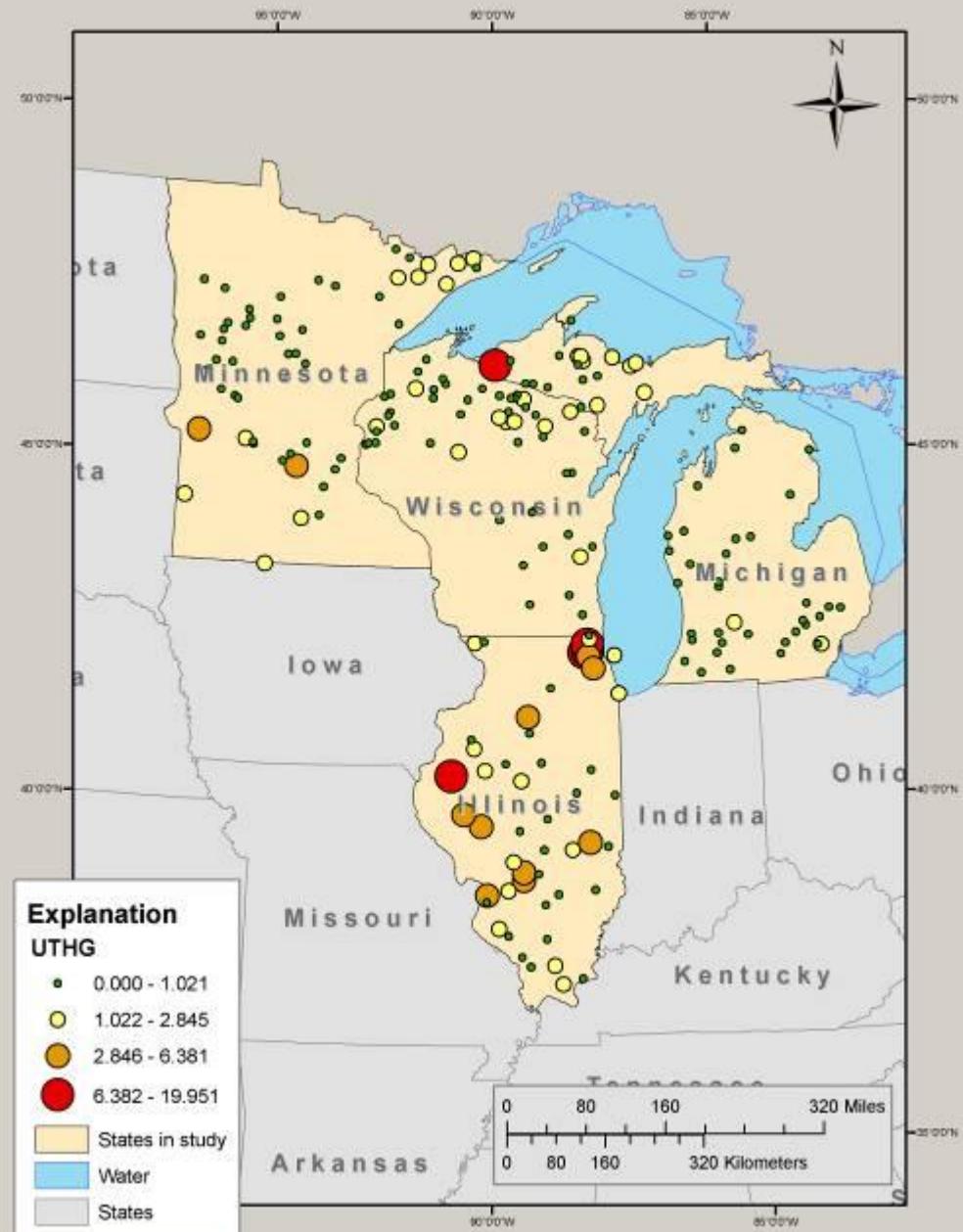
# Upper Midwest Lakes Survey Sampling Sites:

- 234 Individual Sites (EPA lakes plus “enhancemets”)
- Additional 26 hypolimnion samples taken in Michigan
- Clean sampling techniques used by all sampling crews
- Sample containers, gloves, etc... provided by single source (USGS)
- Sample analysis (THg, MeHg, DOC) all conducted at a single lab



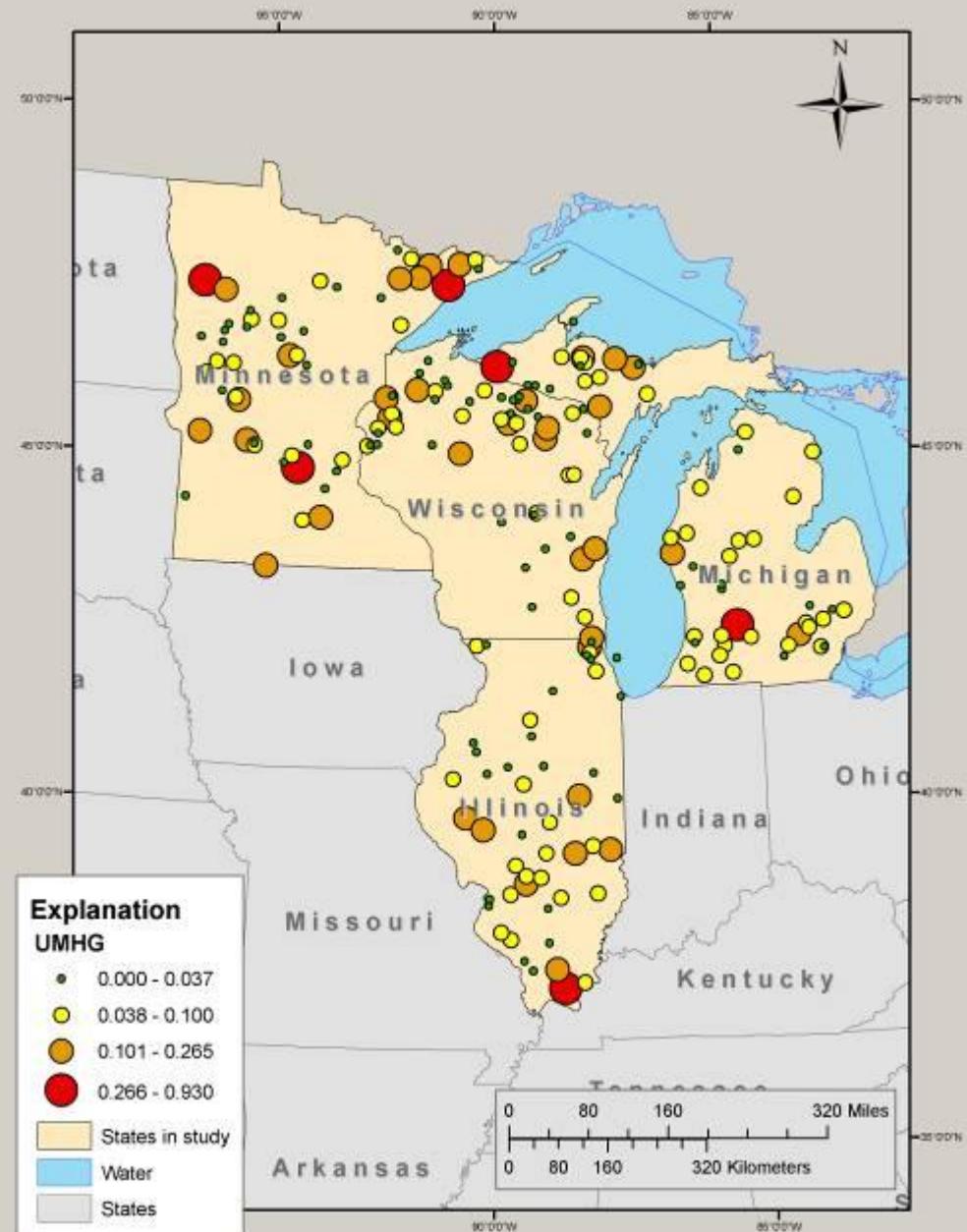
# Total Hg Results:

State	THg (ng/L)	SD
Illinois	2.24	2.62
Michigan	1.13	2.49
Wisconsin	0.68	0.40
Minnesota	0.93	1.04



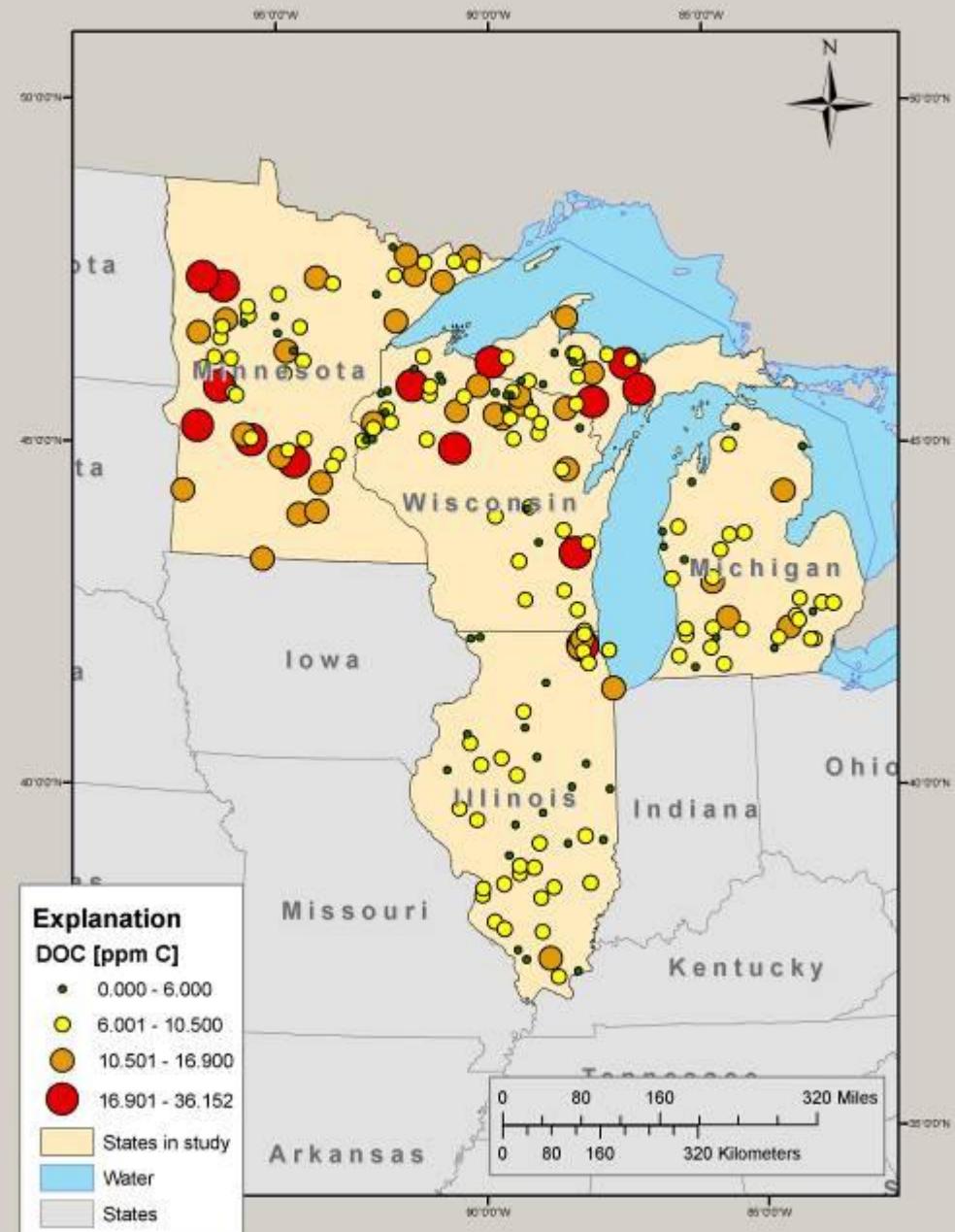
# MeHg Results:

State	MeHg (ng/L)	SD
Illinois	0.07	0.08
Michigan	0.09	0.15
Wisconsin	0.06	0.06
Minnesota	0.09	0.10

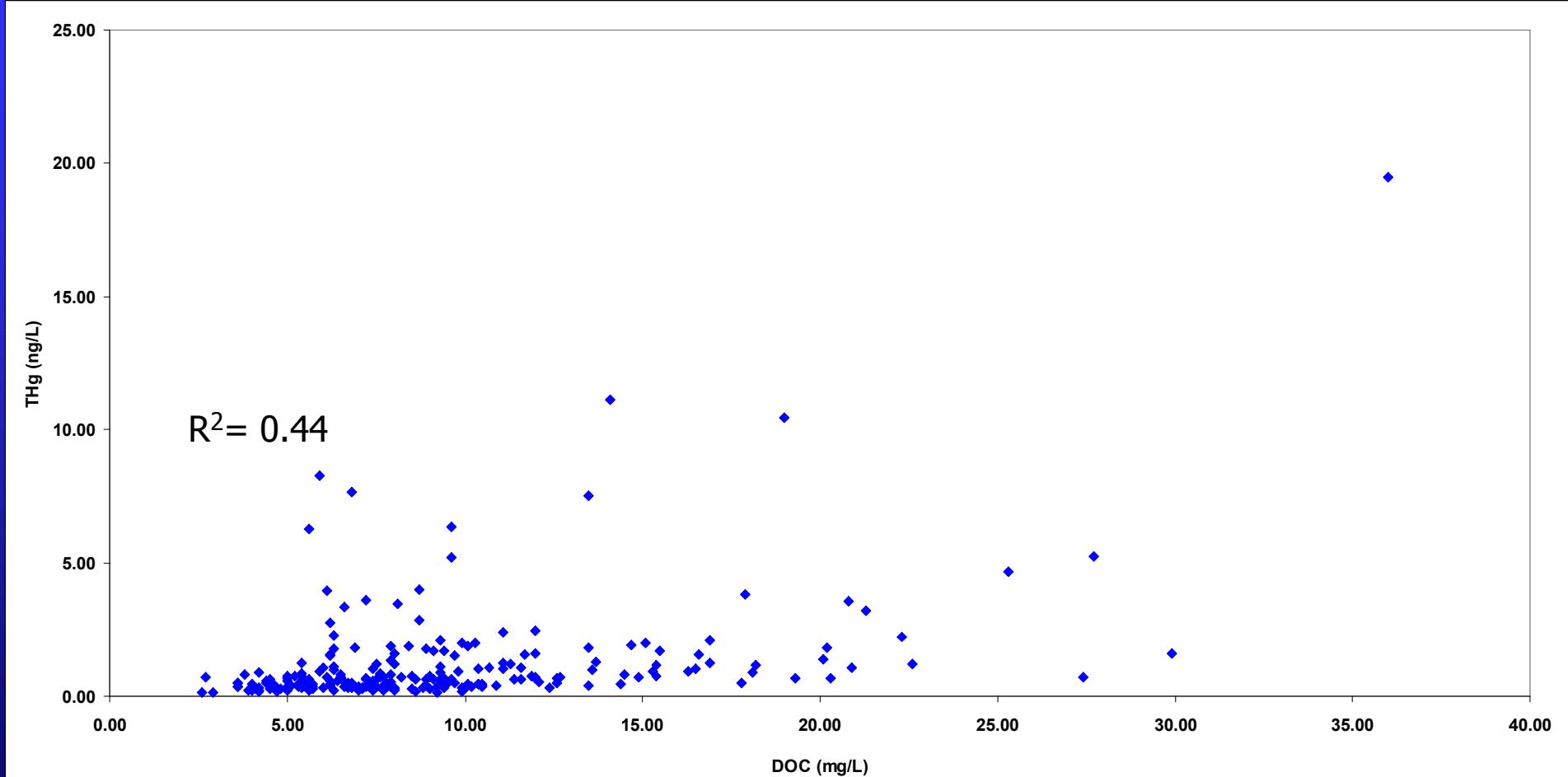


# DOC Results:

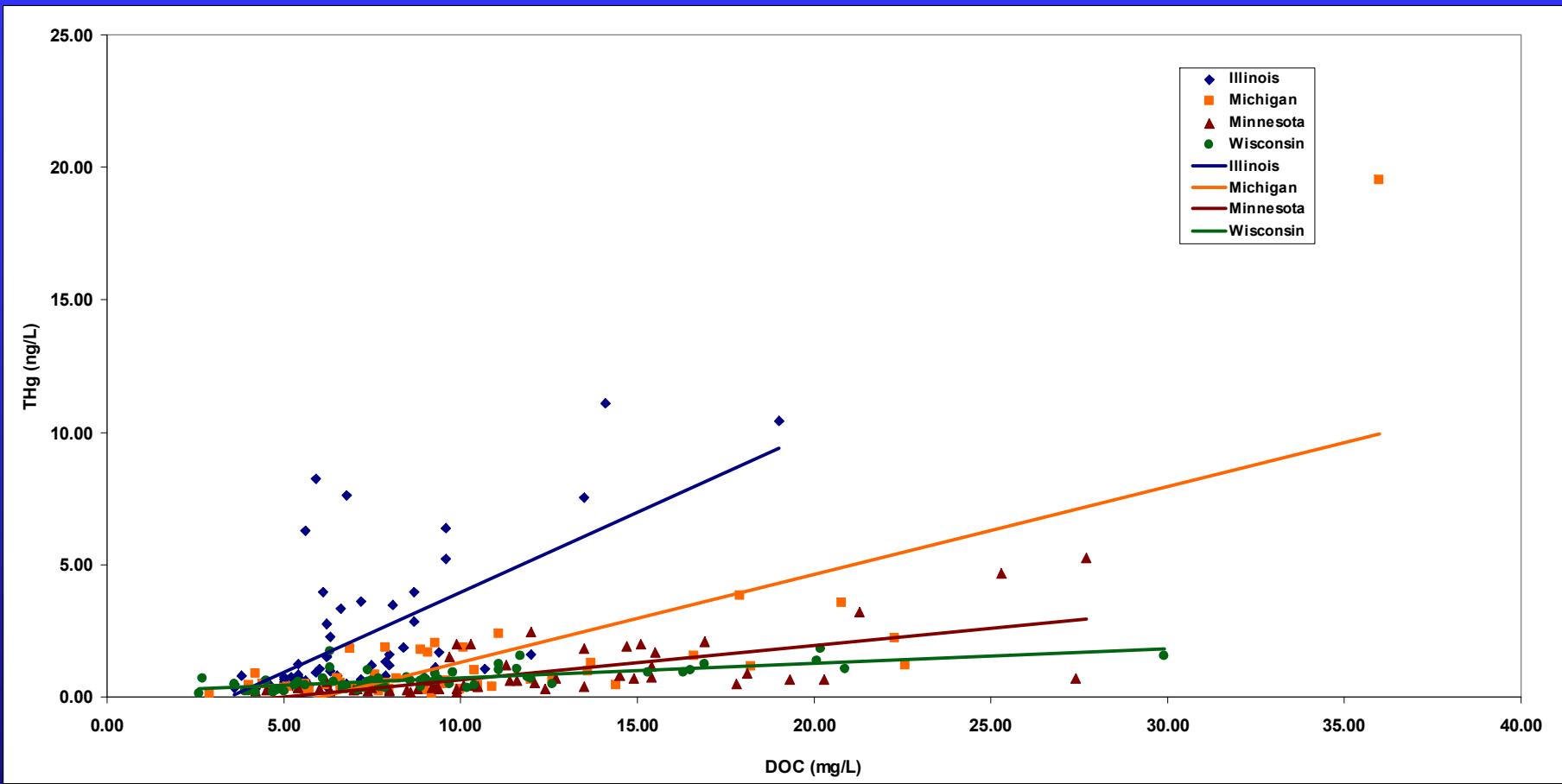
State	DOC (mg/L)	SD
Illinois	7.1	2.8
Michigan	9.5	5.6
Wisconsin	9.5	5.1
Minnesota	12.1	5.4



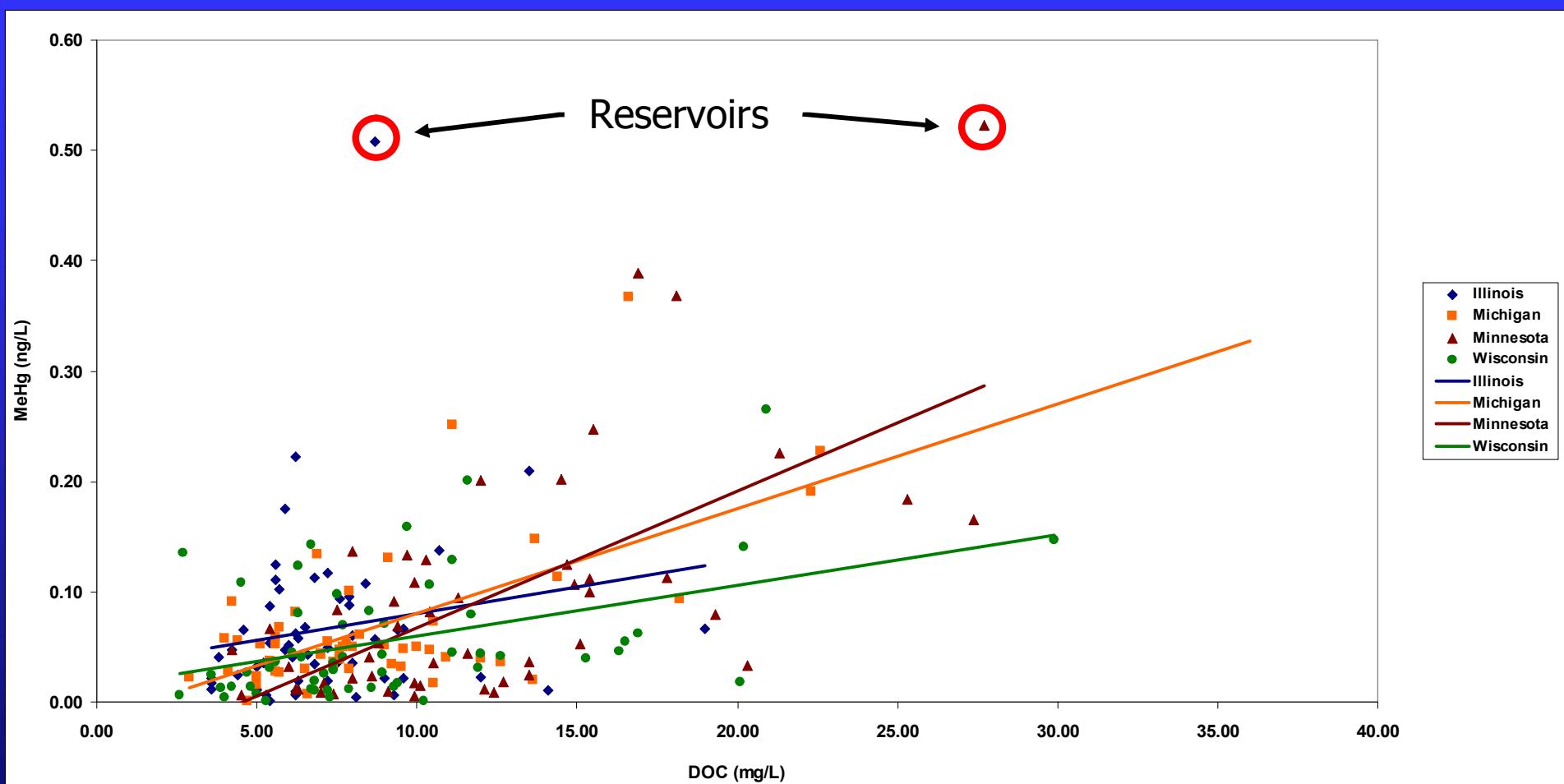
# Is DOC Really a Strong Driver?



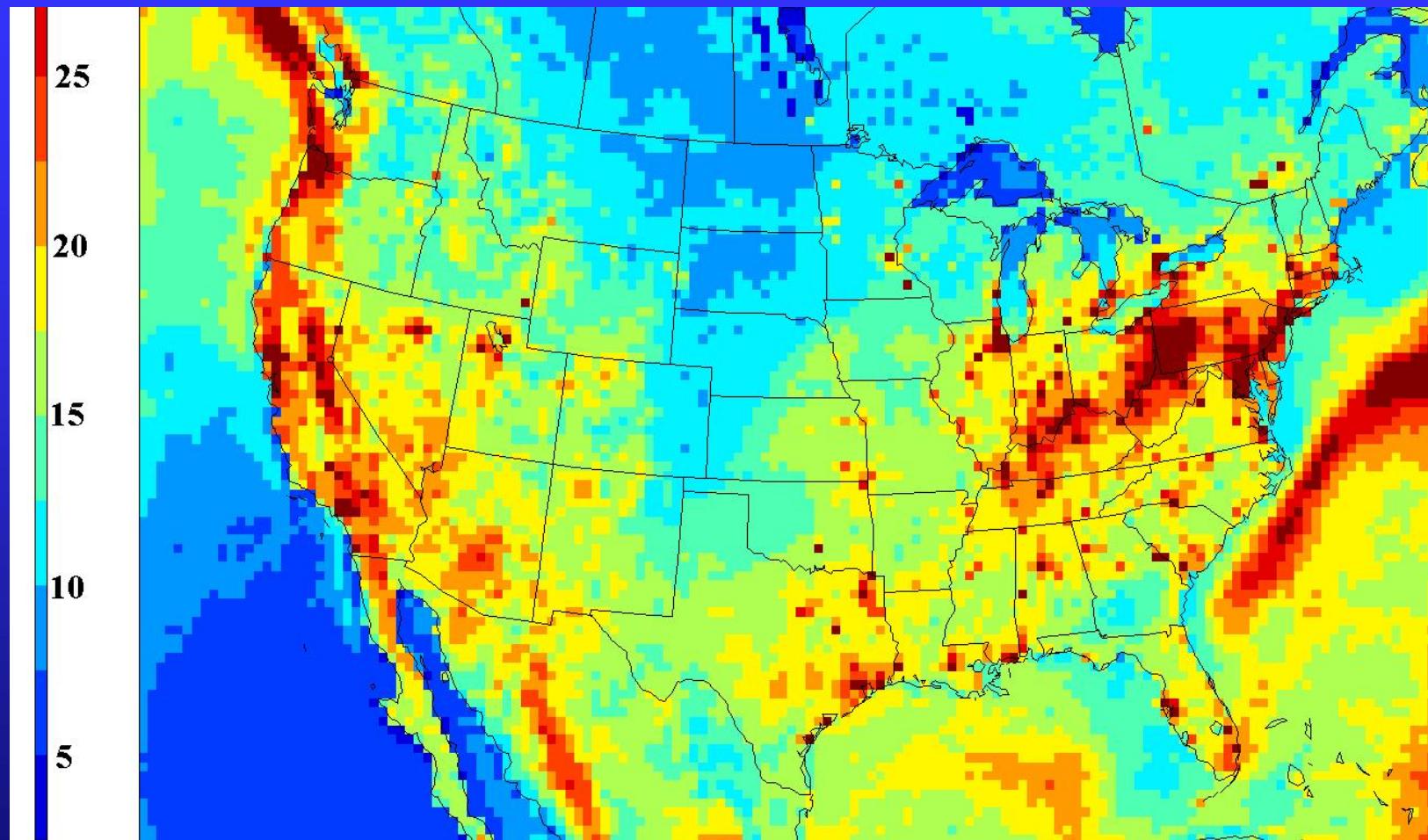
# Yes, the answer is in the details!



# Does water body type matter?



# Corroborating Evidence from CMAQ Modeling



**CMAQ-Simulated (2001) Total Hg Deposition**  
(in micrograms per square meter)

# Implications for Air, Water and Land Management

- Reducing Hg loading (by water ever means) will reduce exposure.
- However, this is only one means to reduce MeHg production in aquatic ecosystems.
- Landscape management actions can decrease or *substantially increase* methylation of inorganic Hg(II), influencing exposure of biota to MeHg.
  - Reservoir construction (water-level fluctuation, carbon additions, flushing rate, temperature, ...)
  - Disturbances (dredging, fire, logging, hurricanes, chemical amendments)
  - Food-web alterations (exotics...)